A. Dean and Jean M. Larsen
Yellowstone Park Collection

QE 79 .P36 1874

BRIGHAM YOUNG UNIVERSITY

3 1197 22779 8276

YELLOWSTONE
NATIONAL PARK

Ron & Jane Lerner Collection
BRIGHAM YOUNG UNIVERSITY

Pumpelly, Collection
Geol. U.S. VII
2830

Contents

I. Hayden – Notes on Geol. Sections about the Headwaters of Missouri & Yellowstone
II. Hayden Notes on Surface Geology of Front Range of Rocky Mountains
III. Hayden So-called Two-Ocean Pass. (Wyomg)
IV Hayden. Lignitic group of Eastern Col. & Wyoming
V Newberry Lignites & plant-beds of western America.
VI. Peale Jura-Trias section of Idaho & Wyoming
VII. Holmes Fossil forests of Yellowstone Nat. Park.
VIII. Scudder – Fossil orthoptera from R.M. tertiaries
IX. Packard – Ancient outlet of Great Salt Lake.

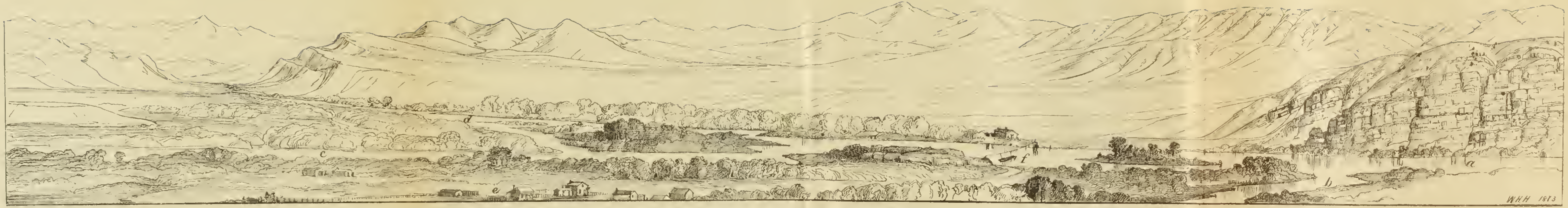
Digitized by the Internet Archive
in 2013

https://archive.org/details/notesdescriptive00hayd

I.

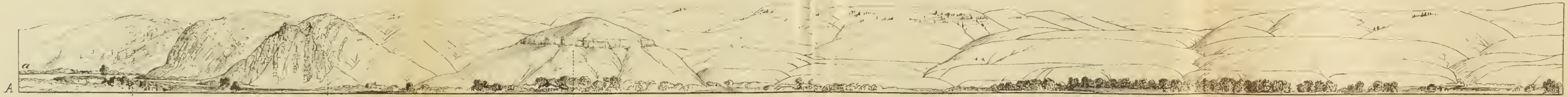
Phk. U.S.

Hayden – Headwaters Mo & Yellowstone



Three Forks of the Missouri, Looking West from the Gallatin Bluffs.

a, Missouri River. b, Gallatin. c, Madison. d, Jefferson. e, Gallatin City. f, Ferry.



a, Ferry. *d. Mouth of Gallatin, and Cañon of the Missouri.* *b, Carboniferous Limestone.* *c, Horizontal Beds of Modern Conglomerate.* *Terraces, & water worn hills of Carb. Limestone.*

Section on the Gallain River.

From Three Forks of Missouri to Mouth of Dry Creek, 15 miles.

Plate I

I.

Geol. U.S.

NOTES DESCRIPTIVE OF SOME GEOLOGICAL SECTIONS OF THE COUNTRY ABOUT THE HEADWATERS OF THE MISSOURI AND YELLOWSTONE RIVERS.

By F. V. Hayden.

It is not intended that these notes shall embrace a complete account of the geology of Montana. They are simply designed to render the beautiful pictorial sections which accompany them more intelligible to the general reader. That these pictorial sections may reach the public sooner, an edition of them is issued in this form. All the sections in this paper represent the scenery along the immediate valleys of the Lower Gallatin and Madison Rivers, with the exception of two, which are fine illustrations of different portions of the Yellowstone Valley.

It is hardly possible for the pencil of the artist to delineate more graphically or minutely the scenery of this interesting country than these sections do. For the geologist very little descriptive text is needed, and for the details of the geology he is referred to the Annual Reports of the Survey for 1871 and 1872.

Should the Survey continue its operations from year to year by suitable grants of money from Congress, all the region, including the Yellowstone National Park, will be re examined systematically and in detail; what we have done up to this time must, therefore, be little more than preliminary to the more thorough work that must come hereafter.

I have always regarded the junction of the three forks of the Missouri—the Gallatin, Madison, and Jefferson—as one of the most interesting geographical points along the Missouri River. Here, within a short distance of each other—a few hundred yards apart—these three great streams unite in one, forming the Missouri River. This junction is most admirably shown in Plate I, upper sketch, which is really a panoramic view of the valley with the surrounding hills. The view is taken looking west from Gallatin Bluffs. At the right hand, at *a*, the three rivers have united into one channel, just at the upper end of a cañon, or gorge through Carboniferous limestones.

In the bottom, and especially on the point between the Madison and Jefferson Rivers, are remnants of Carboniferous limestone, with a few characteristic fossils. These remnants are found at different points in the immediate valleys of these streams, showing most clearly that the broad space now occupied with the lake-deposits, between the Jefferson and Gallatin Rivers, was originally worn out of the sedimentary beds of this locality. In other words, we obtain in this way a glimpse of the tremendous magnitude of the erosive action in past times in this region.

In the background are weathered hills, rising from 600 to 1,200 feet above the valley, underlaid, for the most part, with the limestones of Carboniferous age, inclining toward the north or northeast. Other formations come in, farther and farther in the background, as the Jurassic, Cretaceous, and even remnants of the Lignitic group, which, by the yielding nature of the materials composing these rocks, have given rather a smooth, rounded outline to the surface over an extended area.

This sketch will serve to convey to the reader a conception of the peculiar area which may be noted on the map as included between the Gallatin and Jefferson Rivers, above their junction.

Nearly all the sections described in this paper represent portions of the surface included within this space.

Within this area also is inclosed one of the most complicated and instructive of the great mountain anticlinals.

It is only by taking this position, which seems to be borne out by the facts, that we can unravel the complicated topography of this district. Plate III represents portions of a continuous section, the left-hand end of No. 2 joining on to the right-hand end of the upper section of No. 1, the whole forming the high wall-like range on the east side of the Gallatin Valley, extending from a point below Flathead Pass to the Bridger Cañon to the northward. There is then a short distance in which no rocks older than the Lignitic group are exposed. The older groups, however, re-appear on the divide between the Gallatin and Yellowstone Valley, crossing the Yellowstone and thus form the Lower Cañon.

In Plate VII, lower section, Second Valley of the Yellowstone, looking west from Mount Delano, at the right hand, we see the Carboniferous limestones inclining at an angle of 30° to 50° to the northwest. The Yellowstone River has cut its channel through this high ridge of limestone at right angles.

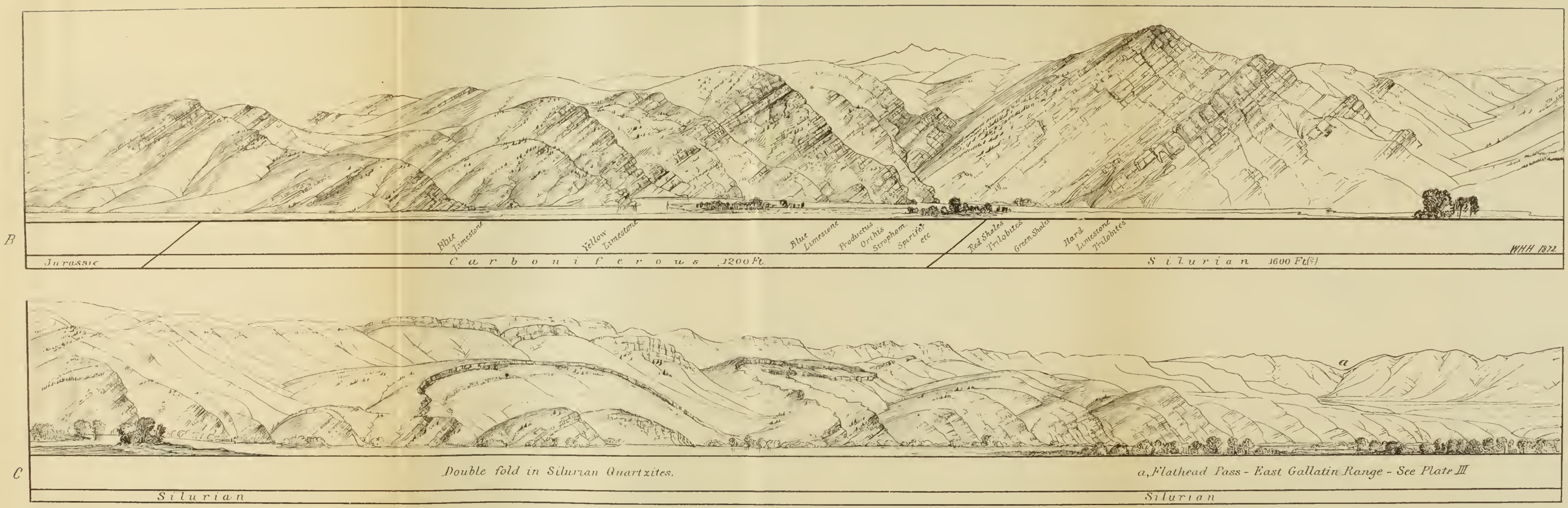
We have here, then, attempted to describe briefly the east or northeast portion of this great anticlinal, which, in future surveys, will be extended far to the northeast, beyond the limits of our geological map.

The structure of this first portion of the anticlinal is well shown in section 7, through Flathead Pass, on page 82 of Annual Report for 1872.

In the section, we observe that the Silurian strata, which are shown on the west side of the ridge, dip past a vertical, while the Carboniferous limestones, which form the crest, are vertical or nearly so, while the Jurassic, Cretaceous, and Lignitic beds incline at various angles to the northeast toward the valley of Shield's River.

It is probable that the corresponding opposite portion of this great anticlinal extends along the east side of the Jefferson Valley, rising like a slanting wall 2,000 feet above the plains below. It crosses the Jefferson near the entrance of the North and South Bowlder Creeks, and through this great ridge the river has worn a vast, deep, narrow gorge called the Cañon of the Jefferson. Here the river, for a distance of five miles, flows through nearly vertical walls of limestone, rising on either side from 700 to 1,200 feet. The general dip is apparently toward the west, or perhaps southwest. A very high ridge extends nearly north and south between the Jefferson and the South Bowlder Creeks. This ridge is cut through by the Stinkingwater, a branch of the Jefferson, thus forming a broad, valley-like opening, through which the road passes from the Jefferson Valley to Virginia City. On the west side of Stinkingwater Creek, the high limestone ridge continues westward to the sources of the creek, to Red Rock Creek and beyond.

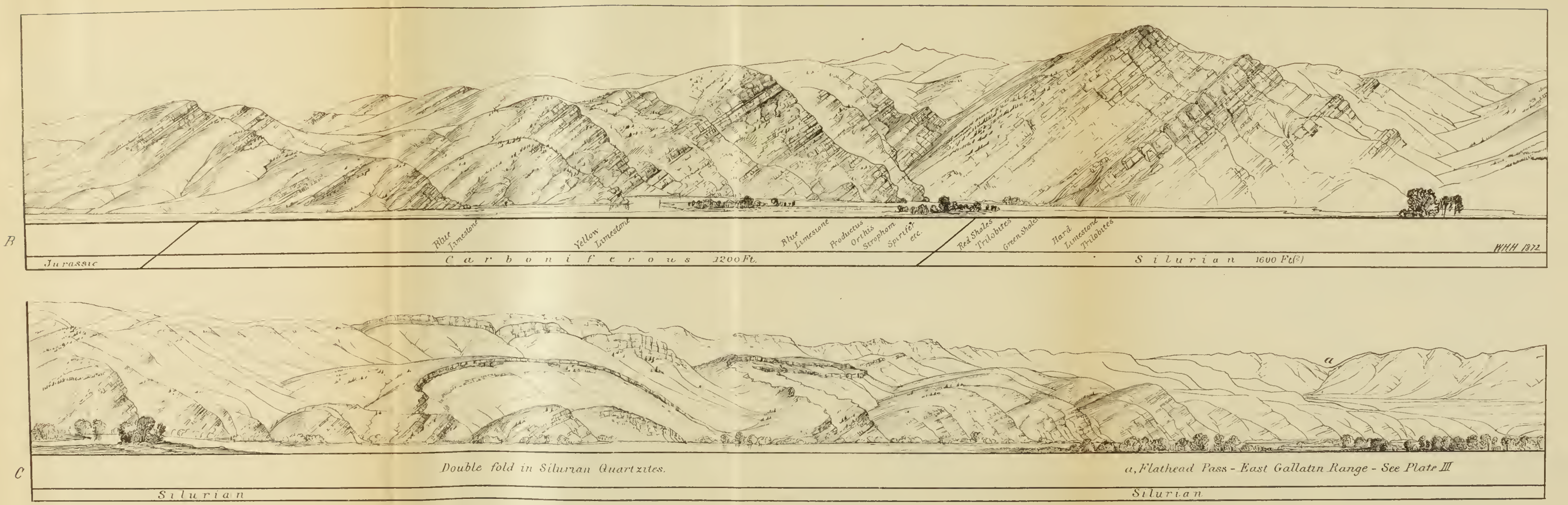
It is probable that the axis of the great anticlinal lies for the most part between the Madison and the Jefferson, forming the granite belt from Sterling to Summit at the head of Alder Gulch. The granitic axis also includes a portion of the country east of the Madison. The general trend of the axis is about northwest and southeast. We may



Section on the Gallatin River.

From Three Forks of Missouri to Mouth of Dry Creek, 15 miles.

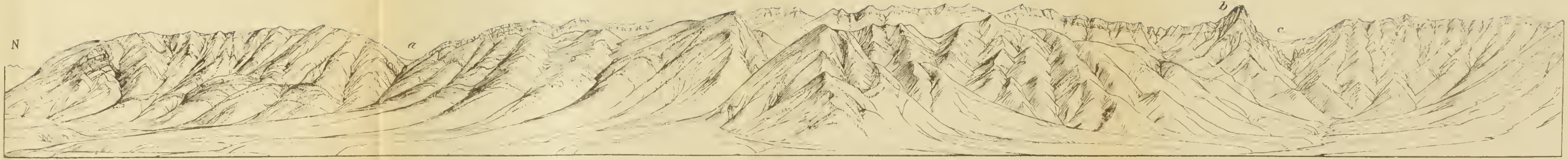
Plate II.



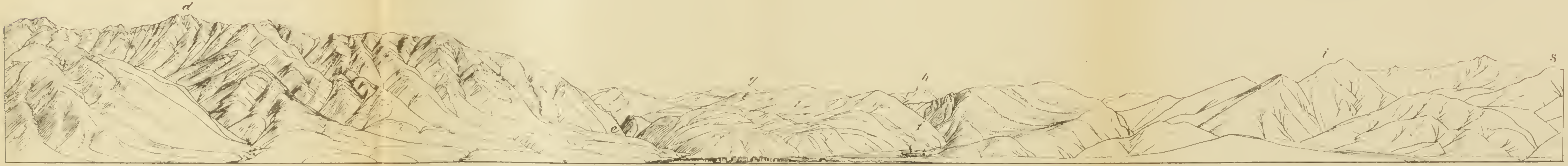
Section on the Gallatin River.

From Three Forks of Missouri to Mouth of Dry Creek, 15 miles.

Plate II.


N
a
b
c
a, Flathead Pass.
Carboniferous Strata form the Summit of the Range. Dipping 20 to 90° E.
b, Liberty Peak.
9000 ft
c, Union Pass.

1.



2.

East Gallatin Range, N. to S. 40 miles.

From road between Hamilton and Bozeman. Looking East

Plate III.

therefore conclude the area embraced in the drainage of the three great branches of the Missouri River—the Gallatin, Madison, and Jefferson Rivers—is broken up by a large mountain anticlinal. Its entire extent is not yet known. It probably covers a somewhat larger area, reaching over into the Yellowstone drainage, and extending north below the three forks.

The structure of this area, although apparently so simple, is very complex, from the introduction of a different force, which seems to have acted synchronously with the one that lifted the granitic nucleus, and which may have been produced by it. This is the volcanic force which has acted most powerfully all over the region. It is by the effusion of the igneous rocks that the sedimentary beds are often thrown into the most chaotic confusion, so that the regular anticlinal ridges are, in many places, entirely broken up and lost. Sometimes we find these beds in patches on the summits of the highest mountain-ranges, and again in the lowest valleys. Faulting on a large scale has been everywhere produced. Over large areas, also, the igneous rocks have been poured out, thus concealing and protecting from erosion the sedimentary beds. On the divide between the Yellowstone Valley and the source of the Gallatin, the trachyte rocks cover all the sedimentary beds, even up to the Lignitic inclusive; and here and there, where the mountain-streams have cut deep gorges into the divide, the Silurian, Carboniferous, Triassic, Jurassic, Cretaceous, and Lignitic can be seen in their order of position. Not unfrequently all the older beds, with the exception of the Carboniferous, had been worn away prior to the effusion of the trachyte, and the beds of limestone crop out along the margins of the mountains and cañons from beneath their igneous covering.

There is a striking example of this along the East Fork of the Yellowstone River, as is shown in Plate X in the "View looking up Soda Butte Creek from Camp on the East Fork of the Yellowstone." We have here 2,500 to 3,000 feet of volcanic breccia and tuffs, mingled here and there with trachyte. This is cut in every direction by little branches into the most picturesque gorges, with very vertical walls on either side, from 1,500 to 2,500 feet in height, apparently stratified and weathered so as to present a peculiar but imperfect columnar appearance. The surface-weathering is in the form of immense castles, battlements, steeples, and towers. Index and Pilot Peaks, in the illustrations in the Annual Report for 1872, page 47, convey a faint idea of the wilderness of unique forms which are presented to the eye over this great volcanic area.

This volcanic material was laid on an irregular surface of limestone mostly of Carboniferous age. Sometimes the red-beds are seen just beneath the breccia beds. From the entrance of Soda Butte Creek into the East Fork of the Yellowstone to its source, a distance of ten miles or more, the limestones crop out on either side of the gorge. Sometimes only ten or fifteen feet are exposed, then again several hundred feet in thickness are seen, with only a thin bed of breccia on the summit.

Over a considerable portion of the Yellowstone National Park, the Lignitic beds crop out here and there, from beneath the igneous covering, in a baked or partially metamorphosed condition, containing fine specimens of plants of various species.

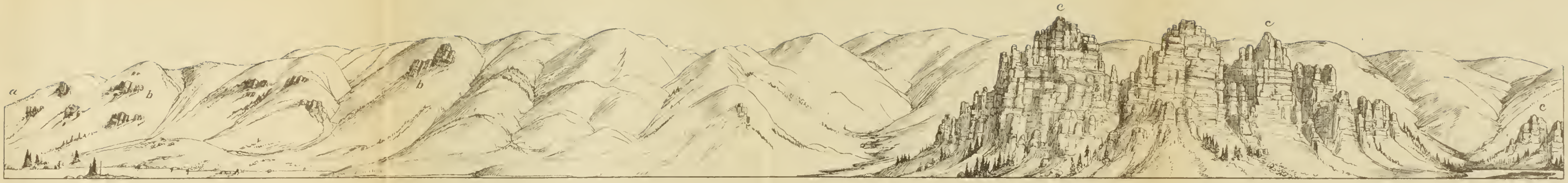
There are also many examples of quite modern volcanic action, in which the basalts have been poured over the modern Pleiocene or lake deposits, and even the local drift.

The evidence seems to be clear that the volcanic effusion commenced far back in the past, at the commencement of the elevation of the mountain-ranges, and continued periodically, even up to the present time, or nearly so.

The drainage was undoubtedly marked out at an early period. The Yellowstone and Madison Rivers rise in the main divide of the Rocky Mountains, while crowded in between them, as it were, is the Gallatin River, which fails to reach the divide with any of its sources. The Gallatin flows through a narrow channel, or cañon, most of the way from the source to its entrance into the Gallatin Valley, a distance of about forty miles. The drainage seems to have originated in a sort of depression, or sag, in the sedimentary crust; for the gorge has there worn through these rocks for nearly the entire distance, and the inclination of the strata on either side is toward the cañon. Nothing seems to have even deflected the river from its course, but it has worn its narrow way directly through highest mountains, as is shown in the six consecutive sections in Plates IV, V, and VI. The erosion of the channel, or cañon, must have commenced with the elevation of the crust, and continued on, keeping pace with the elevating forces. Obstructions from time to time have occurred, which produced in part the numerous lake-basins which we find at the present time in the valleys of all the mountain-streams.

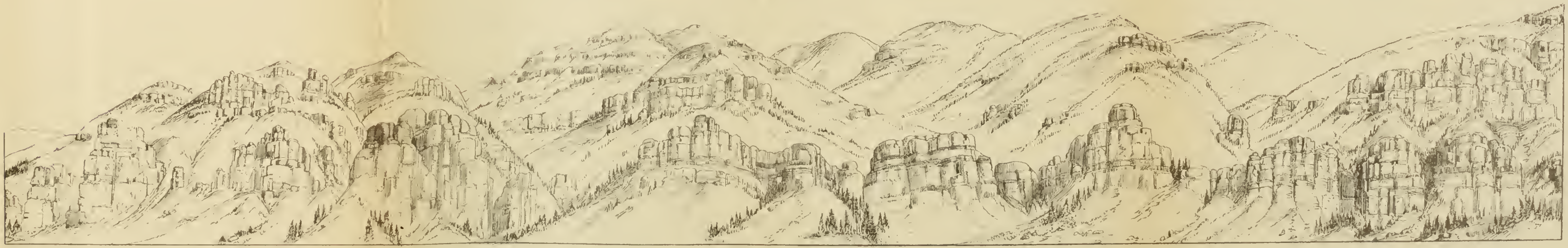
In the previous reports of the Survey, I have treated much in detail the curious old lake-basins that are found so extensively all over the West. There is a certain group of them that might be classed under one head. They have been called Modern Lake-deposits, Lacustrine, &c. Their age is probably Pleiocene, but they undoubtedly overlap what we have usually understood as the Post-Pleiocene period, reaching almost up to the present time. There is, however, a subsequent deposit, which, on the geological map, we have regarded as fluviatile, which on account of its extent must be noted. This oftentimes conceals the Lacustrine deposits. The fluviatile deposits are entirely local, and confined to the drainage-areas in which they are found. They assume importance from the fact that they date back to a period when there was much more water in the streams than at the present time, and in consequence the results of the aqueous forces were much more marked than they are now. There is another important feature, that all the placer-mining is carried on in these deposits. They undoubtedly date back so as to include what is usually understood as the Glacial period in the West. In the various mining-gulches in Montana, these fluviatile deposits are oftentimes of great thickness, made up mostly of much-worn bowlders. In Alder Gulch, for example, which is the valley of a small branch of the Stinkingwater which flows into the Jefferson, $30,000,000 of gold have been taken out. Near the source of the gulch, the bowlders are of great size, but growing gradually smaller toward its junction with the main branch until the fluviatile deposits are made up of rather fine sediments, with perhaps layers of gravel. The vast extent of this deposit conveys a dim conception of the tremendous erosion the surface has undergone in past times. There is comparatively little snow in these regions at the present time, and the streams are never so high that they produce any very marked effect on these deposits, and scarcely nothing so far as erosion is concerned, so that we are led easily to the conclusion that there was a period when the aqueous and most probably the aqueo-glacial forces acted with great power.

As we have previously stated, the Lacustrine deposits belong, in part at least, to a prior period. Perhaps the most conspicuous example of one of these lakes is found at and near the junction of the three forks of the Missouri. The junction of the three branches seems to be the north end of this basin, though immediately below the junction there



Cañon of Gallatin River, East Side No. 1.

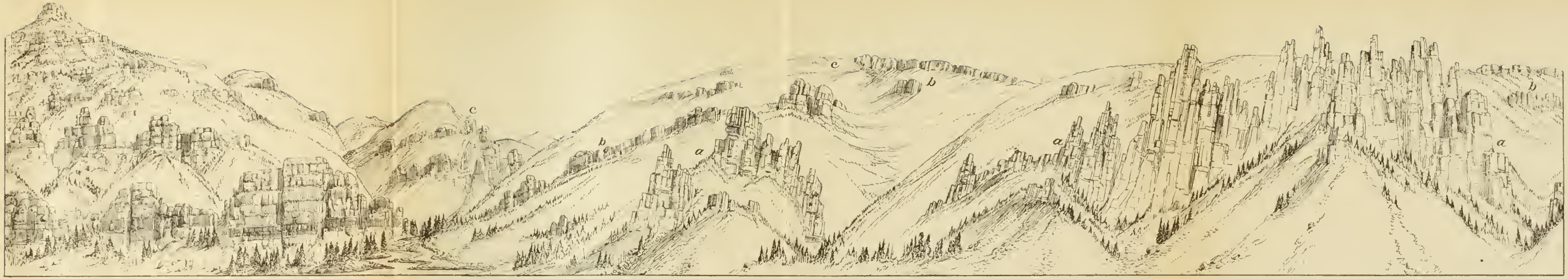
a, Lower end of Cañon. b, b, Granites. c, c, Carboniferous Limestones. Length 5 miles.



Cañon of the Gallatin River No. 2.

Carboniferous Limestones, underlaid by Silurian and overlaid by Jurassic. (3 miles.)

Plate IV



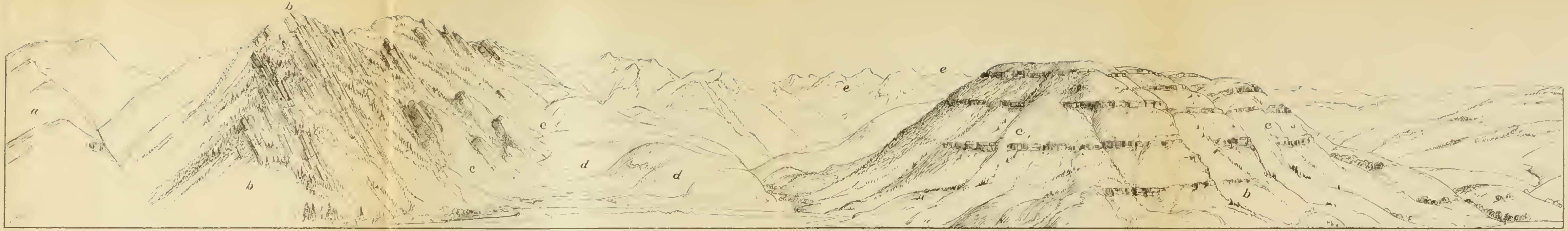
Gallatin River Cañon No. 3.

a, a. Schists, overlaid by Silurian and Carboniferous beds b.b. c.c. (3 miles.)

Cañon of the Gallatin River No. 4.

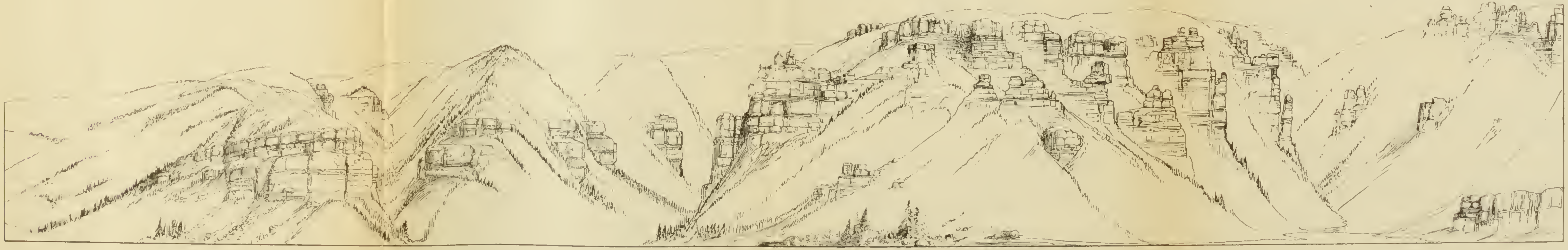
Schistose Rocks.

Plate V.



Cañon of the Gallatin River No. 5.

a, Schistose Hills. b, b, Carboniferous Beds. c, c, Jurassic. d, d, Cretaceous. e, e, Volcanic Range.



Cañon of the Gallatin River No. 6.

Carboniferous Limestones overlaid by Jurassic Beds.

Plate VI.

is an expansion of the valley of the Missouri, in which these deposits occur again to a considerable extent. Indeed, the river-valleys in the vicinity of the mountains may be regarded as having been made up of chains of small lakes, interrupted here and there by a cañon or a mountain-range. These lake-basins, large and small, are, for the most part, the result of erosion. In the general elevation of the country, when the crust was broken up, there were numerous depressions, in which the waters flowing down from the more elevated area may have accumulated; but it is plain that they have been slowly scooped out by water. The general fineness of the sediments would seem to indicate comparatively quiet waters during this Lacustrine period; but the original basins may have been worn out by the combined action of water and ice.

The lake-basin near the junction of the three forks extends up the valley of each of the streams for a considerable distance. It covers the entire valley of the Gallatin and Madison and the interval between the rivers for more than twenty miles above their junction. In the Jefferson Valley, Lacustrine deposits are cut off about ten miles up the river by a high ridge of limestone. This lake-deposit may be estimated to cover an area of about one thousand square miles. In Plate I, showing the junction of the three forks, we see at the right the nearly horizontal strata of Carboniferous limestone, which forms one of the walls of the cañon. This ridge of limestone seems to have obstructed the flow of the waters until the channel was worn through. It must have been much higher than at present, but was gradually worn away, the waters covering a broad surface until they centered in this narrow channel.

In the lower section on the Gallatin River, the Carboniferous limestones are exposed from beneath the lake-deposits in a nearly vertical position. The deposits are much scattered over the surface as we pass up the stream, but the limestones crop out everywhere, showing the character of the basis-rocks. These limestones all present unmistakable marks of having been worn down to their present condition. The modern lake-deposits all hold a horizontal position, or nearly so, and from this fact we infer that there has been no very marked change in the general elevation of the country since their deposition. In Plates VIII and IX, there is a connected series of four sections along the immediate margin of the Madison River, extending from its mouth to the southern border of the basin near the foot of the mountains, a distance of thirty miles. Section No. 8 shows the east wall of the channel of the Madison, as it has been worn out of the Lacustrine deposits. Commencing at the left of No. 4, the horizontal strata may be followed on sections 3, 2, and 1, until the granites of the higher mountain-ranges are uncovered by erosion.

The system of terraces is well exhibited, as well as the myriads of small gullies, or gorges, which are worn out of the sides. In the lower terrace of section No. 1, the vertical schists are seen cropping out from beneath the Lacustrine beds. These Lacustrine sediments are composed, for the most part, of silica and alumina, the former predominating. There is some lime in portions, doubtless derived from the wear of the Carboniferous group. The prevailing color is light brown-gray or nearly white, perhaps in some instances a cream color.

There is a remarkable similarity in the color as well as the composition of these deposits all over the West, in Montana, Oregon, New Mexico, or Texas. The forms which result from weathering are much the same, even though of a different age. The Santa Fé marls, which cover so broad an area in New Mexico, the Arkansas marls, in the valley of the Upper Arkansas River, the Loup Fork group, on the Loup Fork and Niobrara Rivers, are singularly alike, indicating their derivation from the same source. The metamorphic rocks all over the West are composed mostly of quartz and feldspar, the former predominating. It is from the decomposition of these rocks that most of the Lacustrine sediments are derived. Judging from the character of the sediments, there were no violent currents in the channels of the streams in Lacustrine times, unless near their source. The sediments do not seem to differ essentially in fineness where they lap over the flanks of the granite hills at the upper side of the basin.

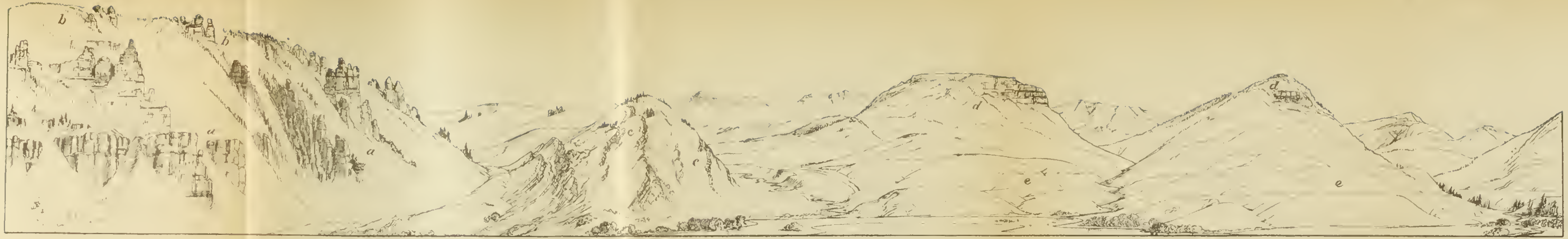
The filling-up of the basin also caused the channel above to be full, so that the fine matter would be distributed over the basin very equably, and settle quietly at the bottom, as in any of our small fresh-water lakes of the present time. The thickness of the deposits in this basin may be estimated at from 1.200 to 1,500 feet. The height of the divide between Madison and Gallatin Rivers ranges from 600 to 1,000 feet above the beds of those streams, so that it is probable that the estimate of the aggregate thickness as 1,500 feet is rather under than over the true one.

The writer was unable to find any of the vertebrate remains in this basin that have usually been obtained from this formation in many other places. Many persons living in the country informed me they had seen remains of turtles, fragments of skulls, and bones of other animals in various places, but the time at my disposal did not permit me to make a careful search. In the side gorges, or gullies, of the Madison, we found most beautiful specimens of silicified wood in great quantities, some of which might be said to be opalized.

In the valley of the Jefferson, near its source, there is one of these small expansions of the valley, in which there is a considerable thickness of the Lacustrine sediments. In 1871, I found there a species of *Helix*, and the jaws of a vertebrate animal of the genus *Anchitherium*.

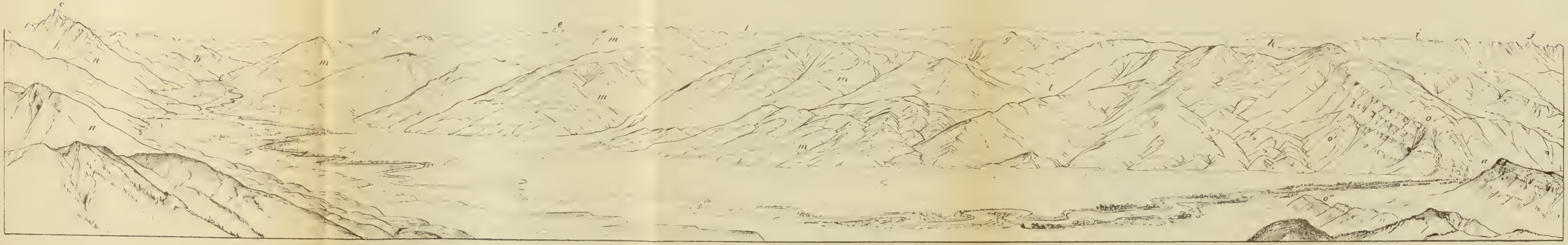
In the American Journal of Science for February, 1876, Messrs. Grinnell and Dana discovered a lake-basin near Camp Baker on Dry Creek, which is evidently one of great interest. In this basin they seem to have found a variety of vertebrate remains, representing two epochs, Miocene and Pleiocene. I am not aware that the lower beds of the White River group had been previously observed in Montana. It is quite possible, as the gentlemen suggest, that the Pleiocene lake on Deep River was connected with those near Fort Ellis and the Three Forks. We may, with perfect confidence, connect them all, for they can be traced with very short interruptions from the sources of the Madison and Yellowstone Rivers and their branches to the points where the rivers leave the mountain-districts for the plains. It may be remarked here that these peculiar Lacustrine deposits are found for the most part only in the mountainous portions; that in the plains, if they ever occur at all, they are of older date. In the valley of the Sweetwater River there are isolated patches of the Pleiocene marls distributed over the Miocene deposits, very similar to those on Deep Creek; but there are here low granite ridges on either side, showing that the foundation-rock on which the modern Tertiary deposits were laid down in that region is granite or gneiss. These same modern Lacustrine deposits occur in the North and Middle Parks, Colorado.

The lower section of Plate VII, "The Second Valley of the Yellowstone," is an illustration of one of the oval Lacustrine basins so common along the rivers. It is about thirty miles long, and will average about thee miles in width. The lake-sediments have been swept out of the basin to a great extent, but there are quite large remnants remain-



Cañon of the Gallatin River No. 7.

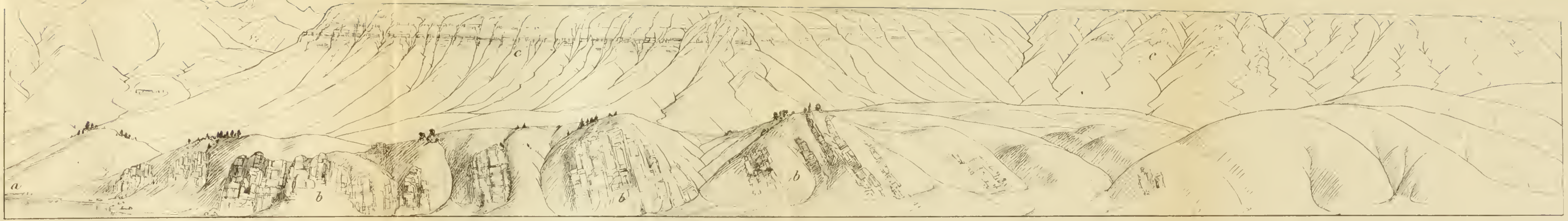
a, a, Carboniferous. b, b. Jurassic. c, c, Jurassic Bed dislocated by faulting. d, Caps of eruptive Rock.
e e Terraces



Second Valley of the Yellowstone, Looking West from Mt. Delano.

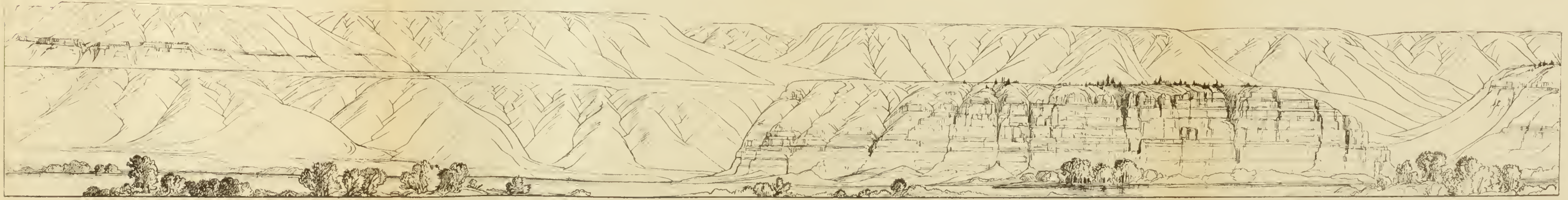
a, Lower Cañon. b, 2nd Cañon. c Emigrant Peak 10600 ft d. Pass to Gallatin Riv. e. Sphynx Pk. f. Blackmore Mt. 10140 ft g. Mt. Ellis. 8400 ft h. Three Forks of Mo. i. Bridger Mt. 9000 ft j Liberty Peak 9000 ft k. Pass from Bozeman to Crow Agency.
l, Trail Cr Pass. m, m, Volcanic Rock. n, n, Schist. o, o, o, Juras, Trias and Carb.

Plate VII



Grand Terrace, Lower Madison Valley, West Side. No. 1.

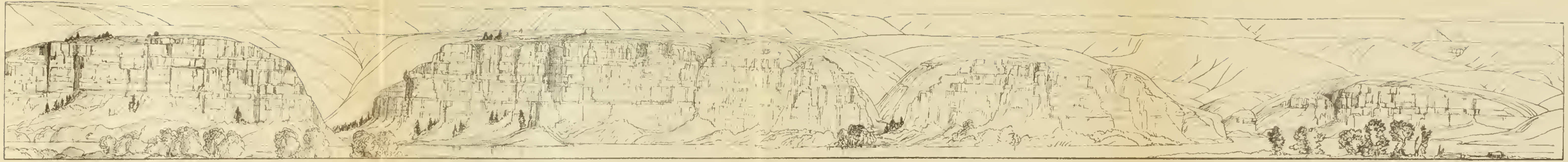
a, Foot of Cañon, Outcrop in front Bluff. b, b, Granites and Schists. c, c, Terrace, Tertiary Sandstone. Height 900 Ft.



Grand Terrace, Lower Madison Valley No. 2.

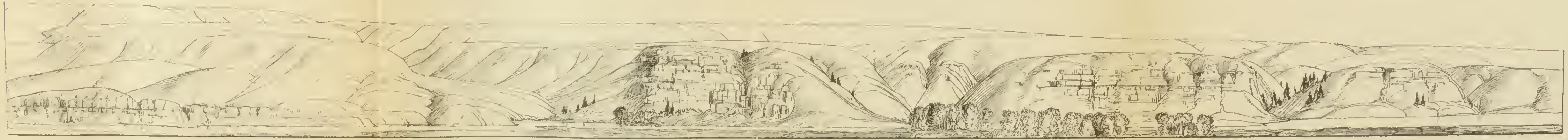
Tertiary Sandstones.

Plate VIII



Grand Terrace, Lower Madison Valley No. 3.

Tertiary Sandstones.



Grand Terrace, Lower Madison Valley No. 4.

Plate IX.

ing, which show clearly that there was originally a considerable thickness of them. At the upper end, broad sheets of basalt have flowed over it, protecting the lake-deposits from erosion. This basin has been entirely scooped out of the mountains, which originally extended across much as we now see them on either side. All over the valleys are remnants of the various rocks, changed and unchanged, just rising above the surface. At the right are seen a group of Carboniferous limestones, which extend directly across the Yellowstone River. The channel which the river has worn through these rocks is called the Lower Cañon, or the Gate of the Mountains. The cañon is about three miles in length, leading into a comparatively small oval expansion, which was originally a lake, and thence into the plains. Inasmuch as all the sedimentary strata from the Lower Silurian to the Lignitic inclusive seem to have been alike involved in the movements of the crust that elevated them to their present position, we infer that these movements were a subsequent event. There is also evidence for the statement that the unchanged rock, prior to this time, extended uniformly over nearly or quite the entire area of Montana. There is no positive proof that the metamorphic rocks were anywhere exposed. The members of the survey searched in vain for any proof of unconformability of position in any of the unchanged strata. Therefore, the vast erosion which has taken place in this region must have occurred during the crust-movements and subsequently. I have before stated that these lake-basins are largely due to erosion. We must conclude, therefore, that depressions were produced during the crust-movements, which received the drainage from the higher lands around, and that the waters thus accumulating gradually carved out these basins as we find them at the present time. These depressions may have been limited in area at first, and may or may not have been produced by the disturbance of the strata; but it is probable that in most cases it is due to the latter cause. We may state, however, in this connection, that the channels of any of the rivers of the West do not necessarily lie along any fissures, anticlinal or synclinal depressions; but the rivers seem to have, in the majority of cases, cut their way directly across the line of fracture, thus carving out deep gorges through the loftiest mountain-ranges. There are numerous examples where rivers seem to have avoided natural depressions, where it would appear that the waters must flow, and cut narrow channels through the hardest rocks. The Gallatin, as well as the Yellowstone, is a remarkable example of this statement. In their entire course, they run almost directly across the line of fracture of the mountain-ranges in the vicinity. The Yellowstone has worn out the enormous second canon with walls 1,000 to 1,500 feet from the granite nucleus. A little to the northwest, the Gallatin flows between walls of granite 2,000 feet high on either side. Still we must admit that in order to produce such results they must have had an original foothold, as it were, to commence their work. The evidence seems to be clear that, during the Tertiary period, and subsequently, the aqueous forces were much more powerful and widely extended than at the present time. All the water-courses and lake-basins, of the West indicate the existence then, of bodies of water compared with which our present rivers and lakes are but rivulets and ponds. We do not find the Miocene lake-deposits underlying the Pleiocene in the vicinity of the mountain-districts. They are found at a long distance from the principal centers of disturbance. We may suppose, therefore, that there were really three important periods which should be considered: First, when the channels of the rivers and the lake-basins were worn out, the aqueous forces operating with great power, and transporting the sediments down into the Miocene lakes of the plains; second, when the waters set back up toward the sources of all the mountain-streams, producing that quiet condition in the lake-basins that enabled the finer sediments to settle upon the bottoms of the Pleiocene lakes, with the strata regular and horizontal as we find them at the present time; the third period may be regarded as the one when the local drift-deposits were made. This period was one in which the forces operating were those of water and ice, or what is understood as the Glacial era of the West. The channels of all the rivers were deepened, and the Lacustrine deposits were in part removed and carried down into the plains.

It was during this period that the terraces and fine sections were here formed, which are so admirably shown in Plates VIII and IX. The deposits of this third period are immense in many localities, concealing all the basis-rocks and giving the peculiar slopes to the base of the mountains as they graduate into the plains. In the mountain-valleys, as, for instance, in the oval lake-basins between the lower and second cañons of the Yellowstone, high bowlders of granite, 25 feet in diameter, have been brought down from the mountains and lodged on the surface of the terraces at different elevations above the present river-bed. The remnants of the layers or floor of basalt that, since the deposition of the Lacustrine sediments, have flowed over the valley, exhibit abundant proofs of glacial action in the very smooth crust, which even now is like enamel. On this basaltic floor, 50 to 100 feet above the bed of the Yellowstone River, many of these large bowlders now rest. Worn masses of smaller size are scattered thickly all over the surface. The greater portion of the local drift is composed of rounded bowlders, varying from a few inches to several feet in diameter, with a small proportion of sand and clay mingled with it. It is at the bottom of this deposit, near what is termed by the miners the bed-rock, that placer gold is found.

It is not pretended that the three periods named above can be defined by arbitrary lines by any proofs that have been left on the surface at the present time. The first period must have commenced either during or at the close of the Miocene era; and there is nothing that indicates any remarkable abrupt break in the sequence of events up to the present time. There was undoubtedly a constant variation in the intensity of the forces that were in operation during all these periods. During the Miocene and Pliocene periods, the animal remains which were preserved in the Lacustrine sediments indicate a comparatively mild climate. The cold period must have approachd gradually, reaching its greatest intensity, covering the mountains and filling the valleys with immense bodies of snow and ice, which slowly melted away, leaving the peculiar lake-basins at the sources of the mountain-streams and morainal deposits, as proofs of its former existence. It is probable, also, that it was during the decrease of temperature, while the waters were subsiding to their present condition, that the terraces were formed. It is not the purpose of this article to present anything like a complete view of the geology of Montana. It is intended simply to render more plain, if possible, the meaning of the beautiful pictorial sections which accompany it. As representations of the varied forms of the scenery in Montana, and, indeed, to a limited extent, in any other portion of the West, they are unsurpassed.

Some of the plates have already been described incidentally in these notes. Plates II and III are closely connected, though not intended to be absolutely parts of the same section. They were sketched from different points of view. The traveler, as he passes up the valley of the Gallatin, toward Bozeman, from the three forks, sees on his left hand, to the east, a high ridge, which rises up like a wall. The abrupt side is toward the valley, and an examination of its structure shows that it is a part of an anticlinal ridge. In Plate III, the right-hand end of Section 1 joins on to the left end of Section 2, and thus a connected view is obtained from below Flathead Pass at *a*, far south to Mount Ellis at *i*. North of Bridger Cañon, the strata are lifted up so that on the west side of the ridge, toward the Gallatin, the metamorphic rocks are exposed, while near the summit of the ridge the Silurian and Carboniferous strata are nearly vertical. From the summit of the ridge, the Triassic, Jurassic, Cretaceous, and Lignitic beds may be seen inclining at various angles, sloping off eastward toward Shield's River. The aggregate inclination of the strata in this ridge is about northeast. Proceeding northward, we find near Flathead Pass that the Silurian beds lie at the base of the ridge, and have been elevated so that they pitch past a vertical 30° to 50°, as is so well shown by the cross-section in the Annual Report of the Survey for 1872, page 84. These two pictorial sections serve to show the weathered forms of these ridges as seen at a distance, rather than the details of structure. The vertical furrows, with here and there a gorge cut directly through the ridge, forming what are called passes in this country, are well shown. From near Flathead Pass southward for several miles, the Silurian beds are lifted up in such a way that the entire series can readily be made out. From the right-hand end of the lower section in Plate II, the Silurian beds extend southward for about eight miles, then the Carboniferous strata overlie them, and are clearly exposed. This section extends along the east side of the Gallatin, and forms the bluffs which have been cut by its waters. The surface erosion of the beds is exhibited with remarkable clearness and perfection. In the Silurian and Carboniferous groups the characteristic fossils are very abundant. They are described in the Annual Report of the Survey for 1872. No Jurassic fossils were found in this immediate vicinity; but near the Yellowstone River, about thirty miles to the southwest, and at Spring Cañon to the southward in the same ridge, they are very abundant.

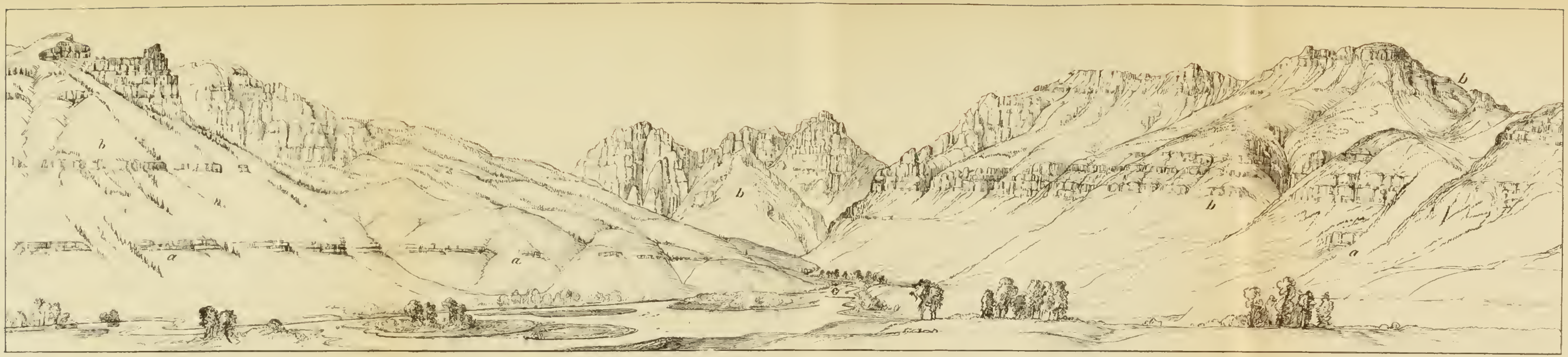
In Plate III, Section 2, the passes of Bridger Cañon and Spring Cañon are quite important from the fact that through one of them the Northern Pacific Railroad must run on its way from the Yellowstone Valley. These are rather narrow gorges cut by the little streams through the ridge, thus exposing an excellent though complicated section of the rocks. The foothills are composed of the Lacustrine deposits, which jut up against the sides of the mountains, sometimes nearly to their summits, apparently without any disturbance, unless it be of a local character. Mounts Delano and Cowen are on the east side of the Yellowstone Valley, their summits rising far above any point on the divide. Mount Ellis, 8,419 feet, is capped with Carboniferous and Jurassic rocks. Bridger Peak, 9,002 feet, is capped with Carboniferous limestones, and Liberty Peak is a portion of the same ridge.

In Plates IV, V, and VI, and the upper portion of Plate VII, we have seven sections that are connected, and represent the east side of the Gallatin Cañon from its opening into the valley on the Lacustrine basin to a point nearly to the source of the river, a distance of about twenty-five miles. The four sections of Plates VIII and IX might have been connected also, as there is but a short interval between them. At the left hand of Section No. 1, we see the rounded foothills underlaid with gneissic rocks. The lower end of the cañon is at *a*. The direction is about north and south, as will be seen by examination of the map. We will commence at the lower or north end of the cañon, and follow up through the several continuous sections and note the principal points of interest. At *c c*, the Carboniferous limestones appear with their peculiar type of weathering. The distant hills are underlaid by the granitic or metamorphic rocks. The limestones seem to have dropped down so that a fault of some importance exists. These Carboniferous limestones rest on Silurian beds. In Section No. 2, still farther up the cañon, we find the Silurian arenaceous limestones forming a rugged escarpment at the base, while on the rather rounded hills the Carboniferous limestones crop out. These hills rise about 1,000 feet above the bed of the river. We thus see that the metamorphic rocks, the Carboniferous and Silurian limestones, present three quite distinct types or forms of erosion, thus giving considerable variety to the scenery.

In Section No. 3, Plate V, the Silurian beds overlaid with Carboniferous limestones continue and pass over the summits of the hills, while from beneath them rise up the reddish feldspathic quartzites, which have weathered into peculiar sharp pinnacles. The river runs for about three miles through a narrow gorge, with vertical walls on either side rising up a thousand feet or more, beset with these sharp angular pinnacles. Above this point, the surface features are softened down, the rocks partially covered with earth, but cropping out in numerous places.

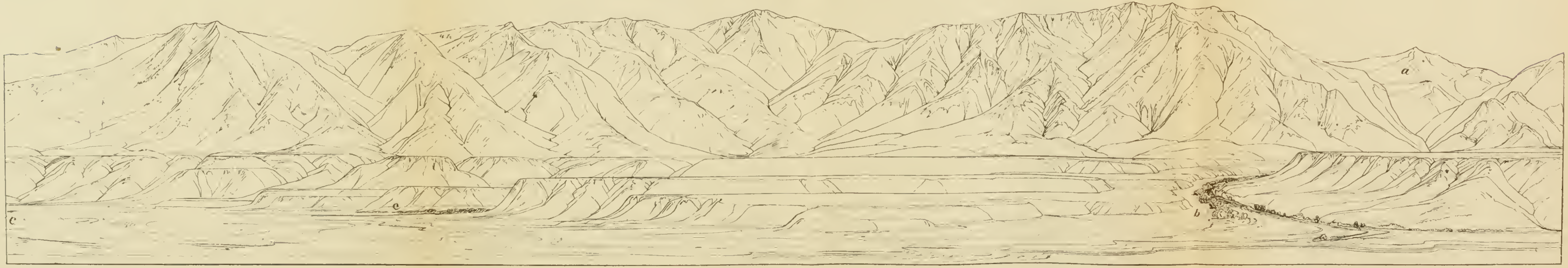
On looking at the geological map of Montana, &c., prepared from the results of the Survey in 1872, it will be seen that there is a small stream flowing into the West Gallatin on the west side, one branch of which rises in Lone Mountain, and the other branch in the Sphynx. Near the mouth of this stream, a high ridge of limestone crosses the Gallatin with a trend about northwest and southeast. On the east side of the Gallatin, the sharp ridges rise up to a height of 1,500 to 2,000 feet, with an inclination 50° southwest. Section No. 5, Plate VI, shows this ridge as it appears on the east side of the river, with the somewhat rounded granitic hills below, on which the limestones lean. The river has cut its channel directly through this ridge, and on the bottom, the worn edges of the upturned shales may be traced across the channel with perfect distinctness. In the section we see the Carboniferous limestones at *b* underlaid with Silurian rocks, resting directly on the granites; and lying against the Carboniferous beds are the Jurassic at *c c*, and at *d* patches of Cretaceous, which seem to have dropped down, as it were; in a sort of Jurassic synclinal.

The Silurian and Carboniferous, with a portion of the Jurassic group, appear to have been lifted up by a vertical force that broke the beds as if they were layers of lumber. In the depression which seems to have been produced by this movement, the Jurassic and Cretaceous beds are seen; but at a distance of about five miles, where, as shown in section No. 6, the Carboniferous limestones rise from beneath the Jurassic in a nearly horizontal position, it would appear that the elevation of the metamorphic rocks, pushing off, as it were, from the sides the sedimentary beds, produced a depression which formed an excellent reservoir for the drainage of the higher lands around, thus giving origin to a stream of water on both sides of the Gallatin. In the background in section 5, we see the group of volcanic peaks which form the divide between the Gallatin and the Yellowstone Rivers. In section 6, the rounded grassy character of the summits of the hills shows the more yielding nature of the Jurassic beds. It is not certain that the true red beds occur in this immediate vicinity. In section 7, we find another dropping-down or faulting of the strata. At *b* the Carboniferous limestones are



View Looking up Soda Butte Creek from Camp on the East Fork the Yellowstone.

a,a, Carboniferous Limestones overlaid by bedded eruptive Rock b,b. c, Soda Butte.



Terrace of the Middle Valley of the Madison. Heights, 10 to 400 Ft.

Madison Mountains. Lower end of Granite Range. Granitic Formation. a, Lone Mt. b, Jackass Creek. c, Valley of the Madison, flat, marshy.

Plate X.

nearly horizontal, while at *c c* the Jurassic beds present a reversed dip, forming a kind of synclinal valley. At *d d* are caps of volcanic material by the eruption of which these remarkable dislocations of the beds may have been produced. There is here an open valley for a short distance where the Gallatin again flows between high vertical walls of Carboniferous limestones with a dip of not more than 1° to 3°. These limestones are weathered into remarkably picturesque forms, castles with pinnacles, turrets, &c. Great quantities of fossils were found here which fixed the age of the rocks beyond any doubt. Plate X is composed of two isolated but very characteristic views of the scenery of this portion of Montana. The upper sketch represents with remarkable perfection the forms produced by erosion of the immense volcanic breccia beds about the sources of the Yellowstone. The sketch was taken from a point looking up Soda Butte Creek, a branch of the East Fork of the Yellowstone.

This small stream may be followed to its source, near the head of Clark's Fork, between nearly vertical walls of volcanic breccia, stratified, 1,500 to 2,000 feet in height. From beneath these mountains of breccia, beds of Carboniferous limestones crop out here and there, sometimes only a few feet above the bed of the stream. again rising to a height of several hundred feet. The hundreds of high mountain-peaks, 10,000 to 12,000 feet elevation above sea-level, which form the divide between the Yellowstone River and the sources of Clark's Fork, Stinkingwater, and Grey Bull Rivers, are composed of volcanic breccia, underlaid with Carboniferous limestones.

This sketch may be said to represent a type of most remarkable scenery, which covers a large portion of the country about the sources of the Yellowstone and the western branches of the Big Horn. Similar forms have been carved out of the breccias and trachyte around the sources of the East Gallatin near Mount Blackmore, of which Palace Butte is an example. A more detailed description of the East Fork and Soda Butte Creeks can be found in the Annual Report of the Survey for 1872, Chapter III, commencing on page 44.

The sketch of the terraces of the middle valley of the Madison may be found described in considerable detail in the same report on page 62. A more connected view is here presented, with the high range of mountains which forms the high divide between the Madison and the West Gallatin Rivers. The middle valley is an expansion or basin about fifty miles in length, and with an average width of five miles. The lower thirty miles presents the most remarkable system of terraces I have ever seen in the West, and I regard them as one of the wonders in this wonder-land. This valley was once the bed of a lake, and the Lacustrine deposits lap on to the base of the mountains at an elevation of about 400 or 500 feet above the bed of the river. The surface of the terraces is composed of superficial drift or the usual Quaternary deposits of this country. Underneath them, especially at the lower end of the basin, the Lacustrine deposits are seen.

From our study of the mountain-ranges in Montana, as well as in other portions of the West, it would appear that the outflow of the igneous rocks is synchronous with their elevations. This is especially the case with those ranges which have a granite nucleus.

The igneous rocks are of different ages. The evidence about the sources of the Missouri and the Yellowstone is that the igneous material was formed more or less through all the periods from the very commencement of the general elevation of the country, which culminated in our present mountains. It may not at all times have come to the surface; but through the vast erosion which has taken place subsequently, the igneous rocks of different ages have been exposed to view.

Over a considerable portion of Montana, Northwestern Wyoming, and the greater part of Idaho, the igneous material, with the accompanying tuffs and breccias, conceal the sedimentary as well as the metamorphic rocks; and they are only exposed to view in the deep gorges of the streams which are produced by erosion. So uniform are these conditions, that one would suspect an intimate connection between the movements of the vast masses of metamorphic rocks which usually form the nuclei of our mountain-ranges and the production of the igneous matter. Is it probable that the movements are so deep-seated as to reach down to melted matter already in that state, and thus affording it access to the surface, or was there sufficient heat generated by the friction of vast masses of rocks upon each other to produce the igneous rocks, as well as the force which has ejected such a vast amount of tuffs and breccia, as we find about the sources of the Yellowstone?

I am not now prepared to discuss this subject, but will simply state that our observations all over the West tend to show a most intimate relation between the eruption of igneous rocks and the elevations of the regular mountain-ranges. Again, an interesting series of observations has been made by the Survey from its commencement, which has been published from time to time in the annual reports, in regard to the channels of our rivers. We find that the channels of our large rivers have not been determined by special lines of depression or fractures, and that there is no necessary connection between them.

It is not an uncommon occurrence to find the channel of a river passing directly through a mountain-range or a ridge, when by a slight flexure it could have occupied a special depression or valley. The West Gallatin River, as is shown in section No. 5, Plate VI, cuts a cañon 1,500 to 2,000 feet in depth, through Sedimentary and Archæan rocks, for several miles, when by an easy flexure, as the surface now appears, it might have occupied areas of special or natural depression.

Nearly every cañon through which any of the rivers or smaller streams of Montana pass, and they are very numerous, present the same peculiarities. The Jefferson Fork presents striking examples of this kind, while the Missouri River below the junction of the three forks, the numerous gorges or cañons are plain illustrations of this statement. We must conclude that since the channels of these streams were marked out, the mountains have been elevated at least the amount of the present height of their summits above the beds of the streams; that the surface at that time was more favorable for the concentration of the drainage-waters along the line of the present cañon, as it passed over what are now the very summits of the mountains, or ridges; that the erosion of the river-channels kept pace with the slow, uniform, long-continued elevation, and thus these enormous gorges may be accounted for.

In my Annual Report for 1872, page 85, I called attention to this feature, and it is undoubtedly applicable to all the great rivers of the West, to the Snake and Columbia Rivers flowing through the vast basaltic walls to the Pacific Ocean, to the Colorado of the West, that has worn out its cañon for more than two hundred miles from half a mile to a mile in depth, and to the Missouri and Yellowstone Rivers from their sources to their entrance into the plains. In the Annual Report for 1872, I made the following remarks:

> Another interesting point I have reserved for discussion at a more favorable time is the formation of cañons and valleys of rivers, which enter into the scenery of the country as a most conspicuous feature. The fact that the streams seem to have cut

their way directly through mountain-ranges instead of following synclinal depressions indicates that they began the process of erosion at the time of the commencement of the elevation of the surface. This is shown all along the valley of the Yellowstone, and more conspicuously in the valleys of the Madison and Gallatin, which have carved immense cañons or gorges directly through two of the loftiest ranges of mountains in Montana. We believe that the course of these streams was marked out at or near the close of the Cretaceous period; and as the ranges of mountains were in process of elevation to their present height, the erosion of the channels continued. The details of the observations which contributed to form this opinion would occupy a chapter or two.

I would be glad to find the leisure at some future period to extend these observations in detail all over the country west of the Mississippi, so far as it has been explored. It should be done by some one; but as these notes are intended simply to convey brief descriptions of the sections accompanying them, it cannot be done at this time. The sections, however, will, I think, be acknowledged by all geologists and geographers to convey marvelously true pictures of the surface features of a remarkably interesting region.

II

Gak, U.S.

NOTES ON THE SURFACE FEATURES OF THE COLORADO OR FRONT RANGE OF THE ROCKY MOUNTAINS.

By F. V. Hayden.

The geological structure of the eastern base of the Rocky Mountains, from Cheyenne to Pueblo in Colorado, has been so carefully studied that but little more can be said that will have the air of novelty. It remains now to present to the eye a more connected view of the topographical features of this region, thus rendering much clearer many points in the geology. The beautiful and accurate illustrations of Mr. Holmes which accompany these notes will convey a clearer conception to the minds of geologists, of the topographical forms, as well as the geological features, of this interesting portion of Colorado, than pages of mere description. With these views before the reader the detailed investigations of Mr. Marvine, Dr. Peale, and Dr. Endlich, as well as those of the writer, in the annual reports for 1873 and 1869, will be far better understood. Therefore, it will not be necessary to repeat in this connection the details of the geology of this region, but the reader is referred to the series of annual reports. Plate IX represents the great Colorado or Front range of mountains, as seen from a point near Denver, commencing north just beyond the northern boundary of Colorado and extending south to Pike's Peak, a distance of about eighty miles in a straight line. In the foreground we see what are termed the plains, a broad rolling surface, gradually sloping from the base of the mountains eastward. The dotted line marks the boundary between the sedimentary strata and the Archæan or Metamorphic rocks which form the nucleus of the range. At different points the uplifted ridges, which are termed in the West "Hogbacks," can be distinctly seen. This view was taken twenty miles or more to the eastward of the immediate base of the mountains, and therefore only the higher ridges were visible to the eye of the artist, but their character can be well understood from these sketches. North of the North Boulder Creek, at *l*, *l*, the ridges of red sandstone with Cretaceous No. 1 are well exposed near the base of the range, but are not shown in the sketch; between the North and South Boulder Creeks at *l*, *l*, and *h*, are some of the most conspicuous ridges of sandstone that are known to occur along the foot of the Rocky Mountains, from latitude 49° south to Santa Fé. They rise to a height of 1,500 feet above the plains at their base. It is difficult to account for the manner in which they have been protected from erosion. It is quite possible, however, that it is due to the fact that they have been partially metamorphosed by heat, and hence their greater hardness renders them less amenable to the influence of the atmospheric forces. That these ridges, all along the base of the mountains, were originally much higher and may have even extended far up the mountain-sides, but have been removed by erosion, there is ample evidence. In many instances they seem to have been almost entirely removed for considerable distances, and again they rise 200 to 500 feet, seldom more, except in this instance. The inclination of these sandstone ridges varies much in different localities. Sometimes they stand nearly vertical. They may be said to incline at all angles from 5° to 80° from the granitic mass. It will be seen that these sketches illustrate a very important point, which has been often repeated in my former reports, the rising of the great mountain-ranges suddenly or abruptly out of the plains. In the foreground we have the Lignitic beds inclining at a very small angle, within a short distance from the granites, varying from a half mile to two miles in width, seldom more. We may infer, therefore, that the force that elevated the mountain-range acted nearly or quite vertically. Whenever the inner ridges stand at a high angle, the beds have been undoubtedly broken off abruptly close to the granite foot-hills, as is well shown at Boulder Creek, and at Pike's Peak in the "Garden of the Gods." The illustration of this vertical uplift of the sedimentary beds, by which they seem to have been broken off abruptly, forming a right angle, as it were, is very common along the base of either side of the eastern range of the Rocky Mountains. In some instances a nucleus of granite will be surrounded with a narrow belt of nearly vertical beds of sedimentary rock, and within a few hundred feet the same vertical strata will lie in a nearly horizontal position. Some of the most important coal-beds in Colorado are opened within a mile east of the granite nucleus in the drainage of the Boulder Creeks, the strata of the coal group inclining at angles of not more than 10° to 15°, and very soon flattening down to a nearly or quite horizontal position still farther to the eastward.

Let us examine the sketch from Denver. To the west, about ten miles, are two quite remarkable table-mountains capped with basalt. Underneath their basaltic caps there is a great thickness of the Lignitic beds, evidently protected from erosion by the hard bed of basalt over them. The valley of Clear Creek separates the two. That they originally formed one bed and spread over a much larger area than at present, seems probable. Between these table-mountains and the granites, the distance is not over a mile in a straight line, and yet there is a thickness of 1,500 feet or more of Lignitic beds, with an important coal-seam, with a series of Cretaceous, Jurassic, and red sandstones, or Triassic, in regular order to the granites. These mountains, with the geology in the vicinity, were described by me in the third annual report of the survey, 1869, and much more in detail, with illustrations by Mr. Marvine, in the seventh annual report of the survey for 1873. From Denver, southward of the Platte Cañon, the ridges are well shown in the sketch just under the dotted line. At a distance, there would appear to be not more than one main ridge, but there are usually several of them, with beautiful valleys between. There are many fine farms among these ridges, and the settlers are very numerous at this time. South of the Platte Cañon there is a narrow belt of the red sandstones extending for about five miles that have been worn into most remarkable picturesque forms, presenting as great a variety, even, as the celebrated "Garden of the Gods," at Colorado Springs. The red sandstones are protected from the plains by a continuous ridge of the Cretaceous sandstones of the Dakota group, while, between that ridge and the granites, there is a belt between a fourth and half a mile in width, in which the red sandstones present a confusion of broken ridges, with their sharp edges projecting above the level, grassy surface, from a few feet to 150 feet in height, with an inclination from the granite mass of 45° to 50° to the east. For this entire distance the Red beds, or Triassic, (?) as they have been usually termed, rest on the granitic rocks. The rolling plains in the foreground are underlaid with Lignitic strata, oftentimes covered with a great thickness of drift composed of sands and rounded boulders, varying in size from a small pebble to 10 feet in diameter. The rounded masses are usually quite small. The city of Denver is built on the Lignitic beds, lying nearly or quite horizontal.

This pictorial section, as well as the one shown on Plate X may be studied with great advantage from several points of view. They present to the eye the relations of the plains with the great mountain-ranges. We can see how the mountains appear to the traveler, approaching them from the eastward, to rise abruptly out of the plains. Denver is 5,197 feet above sea-level, and yet many of the peaks of this great front range, which rises up like a vast massive wall, send their summits above 14,000 feet. The simplicity of the structure of the eastern range, in a general way, is well presented in these sketches. The upturned ridges along the immediate base on the east side, and in some instances on the west side, inclining in opposite directions, show the simple action of a vertical force with very slight tangential movement. In the case of the Laramie range, west of Cheyenne and the Black Hills of Dakota, the full series of sedimentary strata present their uplifted edges on either side of the granite nucleus, so that we cannot resist the conclusion that, prior to the elevation, the sedimentary beds extended in unbroken continuity across the area now occupied by the metamorphic central mass; the missing portions having been removed by erosion during the slow, long-continued process of elevation.

Although there is apparently so much simplicity in the dynamics of these eastern ranges, the details of structure are very complicated and varied. Perhaps the most important lesson taught by these sketches is the great variety of forms resulting from erosion. The glacial period in the Rocky Mountain region has passed away, but it has left everywhere most wonderful exhibitions of its power. Even the highest peaks have suffered more or less degradation, and it is hardly possible to estimate the amount of material which has been worn from the great central granitic mass. Water and ice are still at work diminishing the height of the loftiest ranges, and yet the forces now in operation are very feeble compared with those which performed the work during the glacial period. Indeed, we may presume that the work of degradation commenced as soon as the area now occupied by the mountain ranges arose above the sea; and, therefore, the work of destruction of the original forms has been going on for an almost unlimited period of time, dating back nearly or quite to the Carboniferous period. We may therefore conclude that the present remarkable forms which Mr. Holmes has so accurately and beautifully depicted, are the later results of the handiwork of nature, in her task of earth-sculpture. All through these ranges of mountains are myriads of deep gorges, the channels of the many small streams that, uniting in the plains, form our large rivers. All of these show conclusively that they have been carved out to a greater or less extent by erosion. On either side of the mountain crests are huge amphitheaters, filled with vast quantities of *débris* of broken rocks, the wearing back, toward the crest, of these channels by the combined action of water and ice. There are also numerous oval areas, usually called parks, varying in size from a few acres to many square miles, which have also been worn out to a great extent by glacial action. Vast quantities of drift, morainal deposits, terminal and lateral, are in most cases found in these mountain valleys, detailed descriptions of which appear in our reports, from time to time. All along the base of the mountains this local deposit is most abundant, and it extends far out into the plains. To show its local character we may state that the materials become gradually finer as we recede from the place of their origin. Toward the mountain crest or divide, the local drift is very coarse, made up of blocks scarcely worn; these diminish in size and become more and more rounded by attrition as we move from the crest. Pike's Peak, which towers so loftily over all the other summits in the vicinity, is covered on its top and sides with broken masses. High above timber-line, the sides of the peak are covered with a heavy thickness of glacial drift, forming a fine earth, upon which a thick matting of grass and other herbaceous vegetation is growing. Small lakes surrounded with morainal ridges occur above as well as below timber-line.

The sedimentary ridges along the foot of the mountains, as is shown in the sketch, are cut through at right angles, at short distances, by the numerous little streams that flow down from the mountains into the plains. Most of these channels are dry the greater part of the year. These also show that the erosive action has greatly decreased in modern times. We may therefore infer that, so far as surface forms are concerned, there has been nothing permanent but change; that the process of degradation has gone on from the beginning with varied degrees of power, and that it is going on now continually, but with greatly diminished force.

In describing briefly Plate X, we may commence at the right hand or north end; we see in the distance the source of Monument Creek in the divide which separates the drainage of the Arkansas River from that of the South Platte. The coarse sediments of the Monument Creek group usually jut up against the granite foot-hills with very little inclination, as if the elevation had been very slight since the deposition of the Monument Creek beds. In the foreground near the pine tree, are the bluffs of Lignitic sandstones, which overlook the valley of Monument Creek, and once extended across to the foot-hills of the mountains. At *n* is West Monument Creek, which, with its numerous branches, has carved out broad valleys, as they came down from the mountains, leaving, either in groups or isolated columns, those singular forms figured in the annual report for 1873, opposite page 32, and on this account have suggested the name of Monument Park. At *v* we have the isolated castellated columns seen in the heliotype Plate VII, in Bulletin No. 3. About midway in the profile at *p*, are Austin's Bluffs, a part of the coal or Lignitic series, dipping northeast at an angle of about 8°, and extending off to the northwest, so as to lap on to the granite foot-hills. At the left-hand corner, a portion of the same sandstones seen at the right-hand corner and in the center of the foreground, are shown, with something of the peculiar style of weathering of the Monument Park sandstones. The layer which caps the column, is an iron-rust colored sandstone, harder and less yielding than the portions below. The oxide of iron seems to have cemented the grains of sand and small worn pebbles into a hard rock. Here we have the lowest beds of the Lignitic group, and nine miles east of Colorado Springs, underneath these sandstones, are thick beds of coal, amounting in the aggregate to 20 feet or more. In the valley of Monument Creek, *t*, *t*, the Cretaceous clays are exposed by the denudation of the Lignitic beds, and numerous species of *Ammonites*, *Scaphites*, *Inocerami*, &c., are found. These coal or Lignitic beds once extended uninterruptedly across to a point very near the base of the mountains, and in all probability were connected with the coal-beds at Cañon City, on the Arkansas, a distance of thirty miles in an air line, southwest. The mesa, *k*, *k*, separates Monument Creek from Fountain Creek, and is underlaid with Upper Cretaceous beds, Nos. 4 and 5, with a thick covering of rather coarse drift. This is a most beautiful plateau, overlooking the plain country in every direction. At the point of the mesa, at the left hand, the two creeks unite; only Cretaceous clays of Nos. 4. and 5 are seen.

The Lignitic beds pass very soon beneath a more modern group of rocks, which in the annual report of the survey for 1869 I called the Monument Creek group. North and west of Colorado Springs are a number of extensive coal-beds, and in the sandstones above and below a considerable variety of the peculiar fossil plants have been observed. We know that a great thickness of the Lignitic group is here represented, and in following the valley of the Monument Creek up to the northward no want of conformity between the Lignitic and the Monument Creek groups could be observed. I do not doubt, however, that on the "divide" between the drainage of the Arkansas and the South Platte Rivers there is a group of beds of quite modern date entirely distinct from the Lignitic group, which must bear the name of Monument Creek group. I desire here to correct a statement in Bulletin No. 3, page 210, that the two groups, could possibly be identical; also to correct the description of Plate VII, which is an illustration of the more modern group.

In all cases where I have observed the Lignitic strata near the base of a mountain range, they have partaken fully of the uplift, and incline at high angles usually from the range, but it is not an uncommon thing for the modern Tertiaries to jut up against the granites, or to incline at small angles, from 5° to 15°. It was on this account that I pronounced the Monument Creek group, in 1869, Middle Tertiary or Miocene, and, although differing in lithological character, probably contemporaneous with the White River group farther to the northward, and holding the same relations to the mountain ranges. Professor Cope, in the annual report for 1873, page 430, says that the few vertebrate remains which he discovered in this group show conclusively that it is newer than the Eocene. We know but little of this modern group as yet, and we hope hereafter to secure more definite evidence of its age as well as its relations to the South Park basin and other lake-basins in the West.

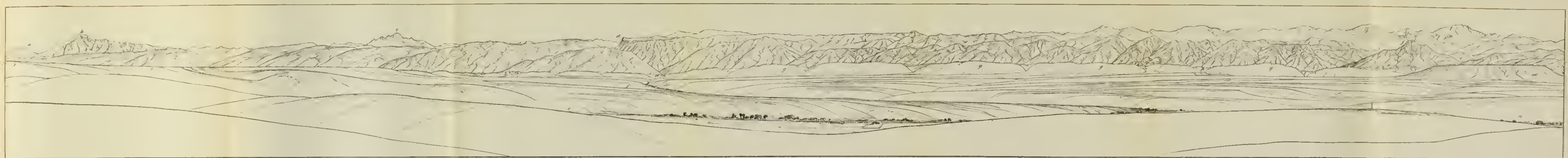
If we look closely under the mountains, about the middle of the profile, we shall see the upturned edges of the sandstones that form a portion of the celebrated "Garden of the Gods." The brick-red sandstones are probably better shown here than at any other locality, and the unique forms which they have received from atmospheric erosion have earned for them their peculiar appellation. In the annual report for 1873, opposite page 200, is a pictorial and anatomical section, which strikingly illustrates the position of the rocks in this region. It will aid the reader much in understanding this profile to read this report. To the left of *y* there is a ridge, lapping on to the side of the mountain, elevated at a high angle, with four cone-shaped points; these are Silurian limestones, which are well exposed in the vicinity of Manitou, near the source of Fountain Creek. Above this point the Monument Creek group juts up against the granites, concealing all the formations of older date. The lessons taught by this profile are much the same as those so well shown in the preceding plate, IX. The mountains seem to rise abruptly out of the plains, as if the vast granitic masses had pushed their way up vertically through the overlying crust, or sedimentary group of beds. At the very base of the mountains, for a portion of the distance, the entire group of sedimentary beds is tipped up at various angles, but in a very short distance eastward from the range only the coal group is seen in a horizontal position. The peculiar forms, both in the mountains and the plains, have been represented by Mr. Holmes with wonderful accuracy and fidelity, and in among the high peaks are the usual gorges or cañons, and all the proofs of terrific erosion in past times.

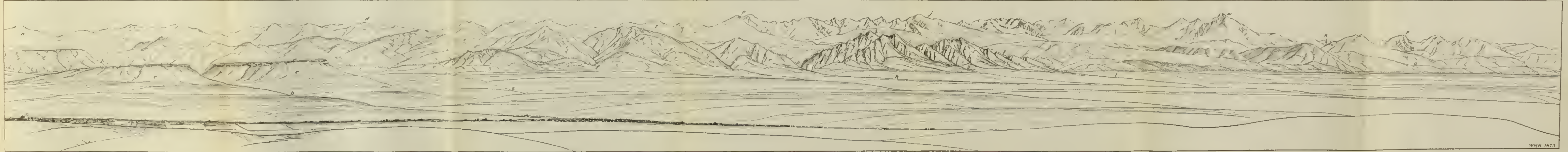
An important fact, however, is illustrated by the profile, which, so far as I know, was first observed by me in 1869 and published in the annual report of that year—that is, the dying out of the mountain-ridges in the plains. The great ranges are usually composite in their character, that is, are made up of a number of smaller ranges. These minor divisions may be continuous for long distances or may break off suddenly, and form some other ridge. The general trend of the aggregate mass of the eastern Rocky Mountain group is slightly west of north, and in many cases, and perhaps in the majority of instances, the minor ranges have an axial trend about northwest and southeast. The consequence is, that all along the eastern side of the great range, the smaller ranges tend to die out in the plains. So that, to one traveling along the eastern base, the ends of these smaller ranges or ridges present a sort of "*en echelon*" appearance. This feature is much more clearly exposed on the Big Thompson Creek about forty miles north of Denver. Section 1, opposite page 20 in the annual report of the survey for 1873, illustrates the manner in which these ridges die out in the plains more clearly. Cheyenne Mountain, at *h*, is an example of a short mountain-range ending abruptly. There is still another point of interest which I believe to be capable of demonstration, though I have not accumulated a sufficient number of observations to express it with confidence. It seems to me that these great composite ranges of mountains have gradually grown to their present size by additions on either side; that, for instance, the single ridge appeared first, as a nucleus, and that, at different periods of time, minor ridges were elevated on either side of the main ridge. This seems to be quite evident, from the different mineral characters which compose the Pike's Peak group. This seems probable, also, from the fact that at one point the red beds, which are at least as old as the Jurassic, appear to have been deposited on the granites after they had been elevated nearly to their present position, while in many other instances the ridges have been lifted up after the deposition of the Lignitic strata. On the south side of the Fountain Creek, Mr. Holmes made some very interesting sketches and studies, which tended to show that these red beds were made up of materials taken from the granites in the immediate vicinity; that the red beds in immediate contact with the granites are made of rather large rounded granitic masses, cemented with sand, that the coarse conglomerate soon became a fine pudding-stone, and fine sandstones, as we gradually move eastward, from the base of the granitic ridge. It is possible that the great Rocky Mountain range was outlined in form, far back in the past, perhaps, even during the Carboniferous period, though it received vast additions during the Cretaceous and Tertiary epochs.

PLATE IX.

View of the Colorado or Front Range, taken from a point near Denver. The two profiles on this plate are continuous; the right-hand end of the upper one joining on to the left-hand end of the lower one.

U.S Geological and Geographical Survey of the Territories





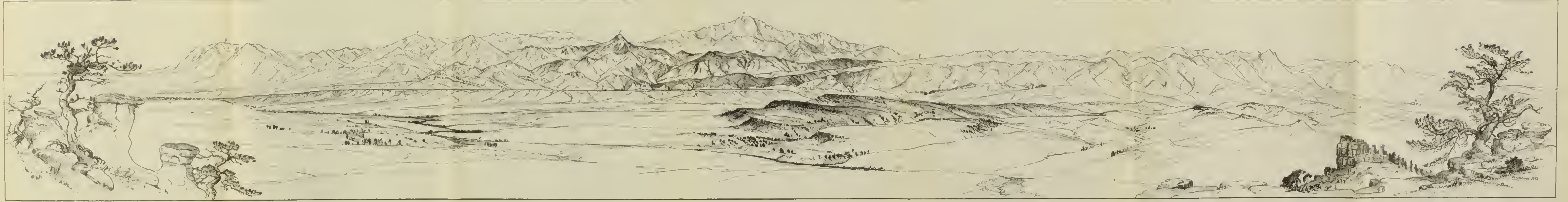
The GRANITES occupy all the elevated areas beyond the dotted line This line follows the upturned edges of the sedimentary strata CRETACEOUS rocks are exposed in the hogbacks gggg above, and sss below behind these are the RED BEDS rr LIGNITIC Strata and DRIFT cover nearly all the plain VOLCANIC Rock caps the Table Mts & occurs at m on Green Mt at v near Ralston's Creek and on the Arkansas Divide t.t

THE FRONT OR COLORADO RANGE
From near Denver

PLATE X.

View of the Pike's Peak Group, taken from bluff east of Monument Creek.

U.S Geological and Geographical Survey of the Territories



a. Colorado Springs b. Cheyenne Mt c. Cheyenne Cañon. d. Bear Creek e. Monte Rosa · Red Beds k.k. Mesa – l. Camerons Cone m. Garden of the Gods. n. Location of Manitou o. Pike's Peak pp. Austin's Bluffs. q. Ute Pass r. Queen's Cañon s. Glen Eyrie g. Lower Cretaceous u. Monument Cr u. West Monument Cr v. Castle Rocks x. Monument Park y. Coal Series

THE PIKE'S PEAK GROUP

From Bluff East of Monument Creek

III. Yak. U.S.

Art. XV.—The so-called Two-Ocean Pass. (Plates III, IV.)

By F. V. Hayden.

This somewhat singular geographical feature has never yet been clearly explained, though it is noted on some of our maps as far back as 1851. It was known to the old trappers of a still earlier period, and they had a tradition of its existence. So far as I can ascertain, the first published notice of it is found in Capt. W. F. Raynolds's Report of the Exploration of the Yellowstone in 1868, page 11. Captain R. writes as follows:

"Bridger also insisted that immediately west of the point at which we made our final effort to penetrate this singular valley (Yellowstone) there is a stream of considerable size which divides and flows down either side of the water shed, thus discharging its waters into both the Atlantic and Pacific Oceans. Having seen this phenomenon on a small scale in the highlands of Maine, where a rivulet discharges a portion of its waters into the Atlantic and the remainder into the St. Lawrence, I am prepared to concede that Bridger's 'Two Ocean river' *may* be a verity."

Again, Captain Jones, of the United States Engineers, in his report of a Reconnaissance of Northwestern Wyoming, gives a brief description of this pass, which attracted some attention at the time:

"At this divide occurs a phenomenon, probably the one referred to by the early trappers as the 'Two Ocean Pass.' Marching at the head of the column where the trail approached the summit, I noticed that the riband of meadow, in which the stream lay we had been following, suddenly dropped away in front of us with a contrary slope. I could still see the stream threading it, and for a moment could scarcely believe my eyes. It seemed as if the stream was running up over this divide and down into the Yellowstone behind us. A hasty examination in the face of the driving storm revealed a phenomenon less startling perhaps, but still of remarkable interest. A small stream coming down from the mountains to our left I found separating its waters in the meadow where we stood, sending one portion into the stream ahead of us, and the other into the one behind us—the one following its destiny through the Snake and Columbia Rivers back to its home in the Pacific; the other, through the Yellowstone and Missouri, seeking the foreign water of the Atlantic by one of the longest voyages known to running water. On the Snake

River side of the divide the stream becomes comparatively large at once, being fed by many springs and a great deal of marsh." In figure 3, plate III, I give a copy of Captain Jones's map of this locality.

During the past season, the writer, on his return from the Yellowstone Park, passed over this divide, and made a somewhat careful study of it. The chart, which was sketched on the spot by Mr. W. H. Jackson, shows the exact character of the drainage.

This pass is located about longitude 110° 00′ and latitude 44° 05′. Atlantic Creek is a branch of the Upper Yellowstone River. The party with which the writer was connected passed up the east side of the Yellowstone Lake to the mouth of the Upper Yellowstone River, and thence up the valley of that stream about thirty miles to what may be called the Three Forks, near Bridger's Lake. The east fork bears the name of Atlantic Creek. From the Three Forks the party passed up the valley of Atlantic Creek to the southwest, for the most part over a grassy valley, which was enclosed between vertical walls of volcanic breccia 1,000 to 1,200 feet in height. This valley is purely one of erosion. The breccia itself is of very modern age, probably of Quaternary date, and the wearing-out of this great groove must have been an exceedingly modern event. So far as can be seen from the summit of the mountains on either side, no divide can be observed. The erosion seems to have produced a gentle slope on either side of the watershed. At the summit, not over ten miles from the junction of the Atlantic Creek with the Upper Yellowstone, the elevation, 8,081 feet, is not more than 150 feet above the valley of the main stream. The valley is at first quite narrow; but it gradually expands into an open, grassy meadow, which, near the pass, becomes one-third of a mile in width, and gradually closes up again into a cañon on the Pacific slope. So obscure is the drainage that we camped the night of October 3, 1878, within a fourth of a mile of the water-divide, but did not perceive it until we commenced our march the following morning.

The conditions are as follows: The summit of the pass for a distance of about half a mile is so nearly level that a marsh is formed, which, in times of high water, becomes a small lake. A portion of the waters from the surrounding mountains accumulates in the marshy meadows, and gradually gravitates from either side into two small streams, one of which flows to the northeast, the other toward the southwest. On the east side of the divide there is a depression or gorge in the mountain, which is occupied by a small stream that at the time of our visit flowed in a well marked channel toward the northeast into Atlantic Creek. This is the well-known Two-Ocean Creek. At the base of the mountain-side (*c*), a small stream rises from a sink-hole, or spring, which at the time the writer saw it (October 4) was nearly dry, and but little water was running in Two-Ocean Creek (*a*). This spring-hole was not separated from the latter creek more than six feet, and a small dry channel connecting it with *a* showed that in times of high water a portion of the water that started down the mountain-channel (*a*) broke over the side into the spring-hole (*c*), and flowed thence through channel *c* to the Pacific. Lower down in the Two-Ocean channel are two places, shown by dotted lines, where there are two old channels connecting in time of high water with channel *c*, showing that a portion of the waters that started down the mountain-side for the Atlantic was diverted toward the Pacific. On the opposite side of the pass there is a similar depression in the breccia wall, down which, at the time of the melting of the winter's snows, much water flows.

The points *b* and *d* are close together, and the waters of the grassy meadows, which lie between them, probably separate, a part taking one direction and a part the other. The little lake or marsh in the center, of course, furnishes a supply or reservoir for both. Although the simple separation of water on a divide is not an uncommon occurrence, yet the conditions observed in this case are rarely repeated, and have not before come under the writer's observation. Small lakes upon the summit of a water-divide, with drainage from either side, are not uncommon from the north line of the United States to Mexico. On the divide between the Yellowstone and Snake River drainage, we often find small lakes or reservoirs of water which in the wet season send small portions to the Atlantic and to the Pacific.

The following are examples of peculiar forms of drainage, which bear some relation to that of the "Two-Ocean Pass":

Figure 1 was observed by Mr. A. D. Wilson, of the Survey, in British Columbia, between Fort Douglass and Lillooet. From *b* to *c* via *a* is about 100 miles' travel. The lake at *a* lies on the summit of a mountain, and is fed principally by springs; its water runs either way through other lakes 25 or 30 miles long, and finally flows into Frazer River at *b* and *c*.

In Fig. 2 is given a sketch of a case where a small mountain stream divides and runs in two channels to the main creek. It occurs in the Wind River Mountains, near the source of the Popo Agie Creek, a branch of Wind River. The small stream enters a depression at *a*, from which its waters find their way out, partly to the right and partly to the left of the rocky hill *d*, and empty into the main stream at *b* and *c*.

Not far from this locality is another example similar to the above, in which a mountain torrent descends against the upper end of a great slide of rock, and is broken into two nearly equal parts, and so descends to the main creek.

Plate III.

Fig. 1.

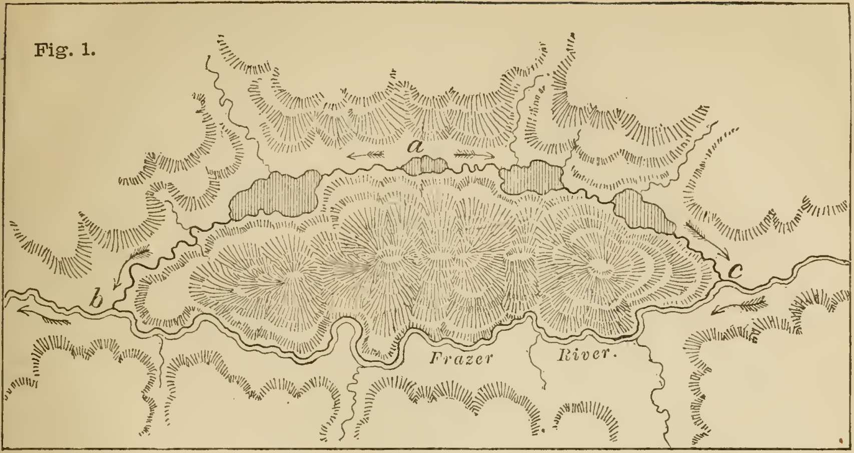


Fig. 2.

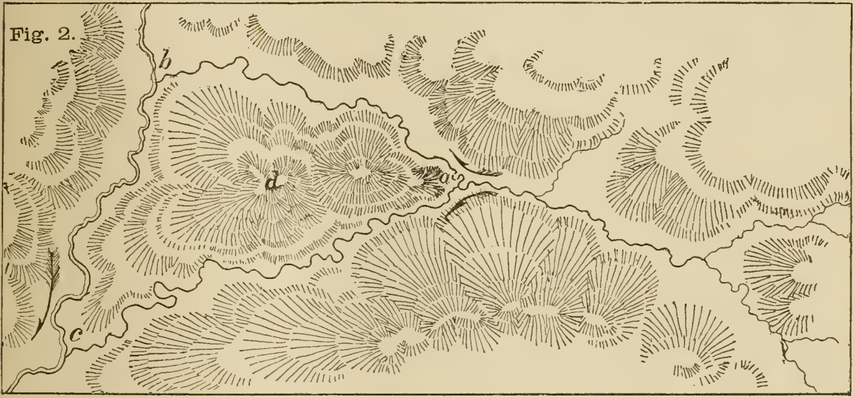
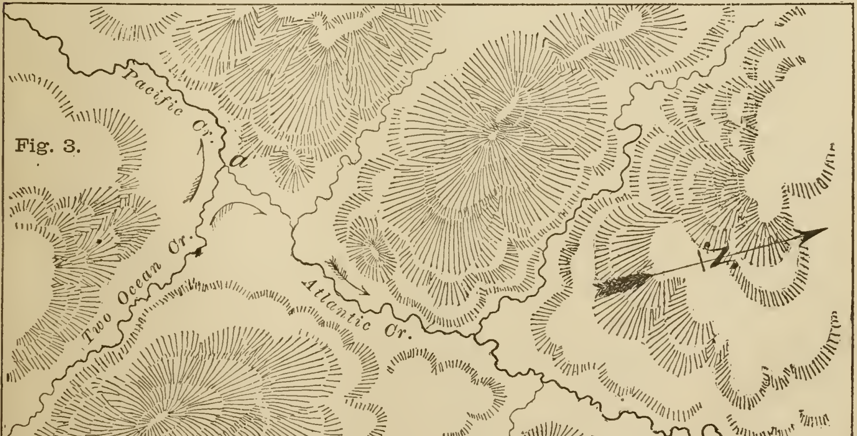
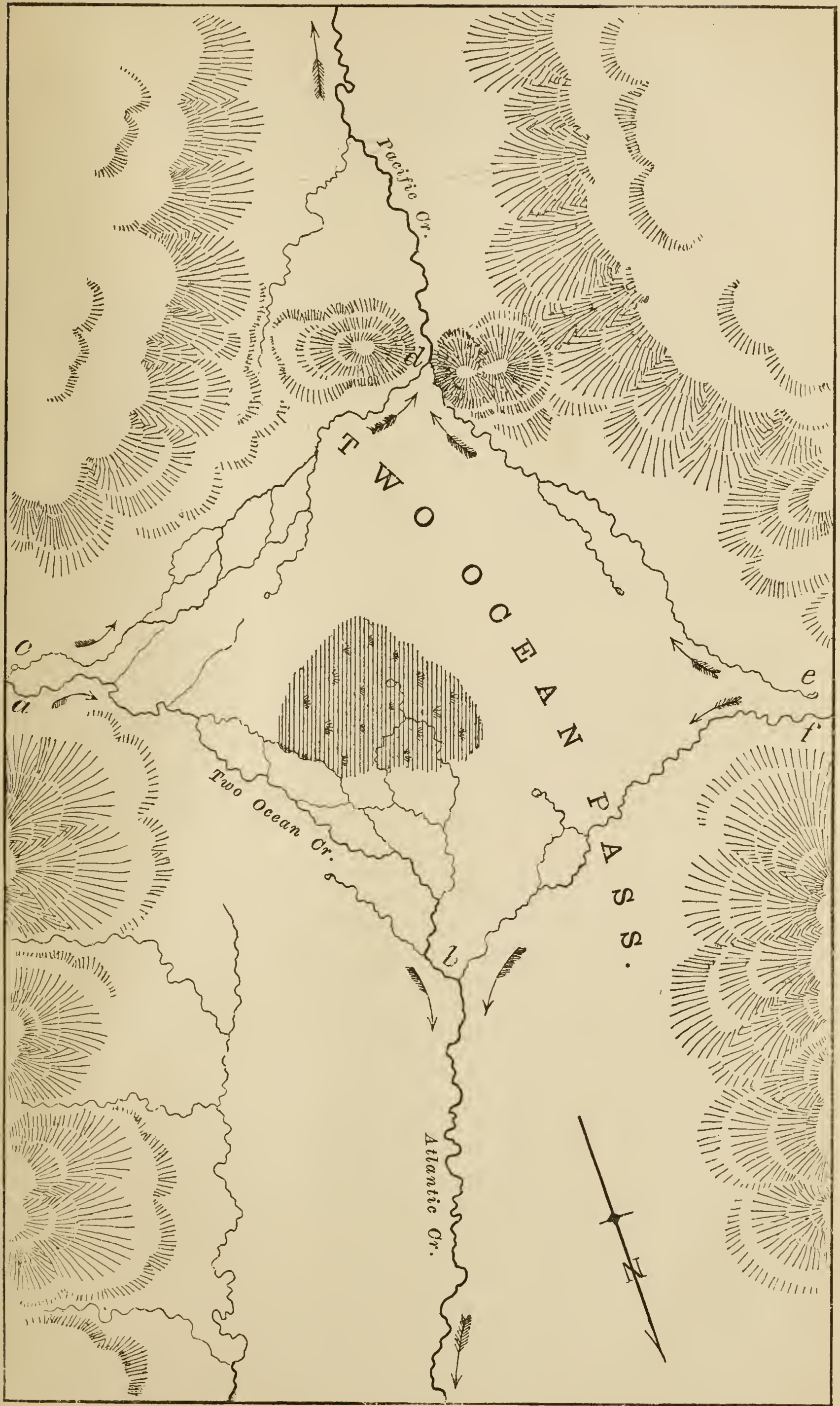


Fig. 3.




Pacific Cr.
d
c
a
TWO OCEAN PASS.
e
f
Two Ocean Cr.
b
Atlantic Cr.
N

IV

Fak. U.S.

NOTES ON THE LIGNITIC GROUP OF EASTERN COLORADO AND PORTIONS OF WYOMING.

By F. V. Hayden.

The difference of opinion that has arisen in regard to the age of what I have hitherto called the Lignitic group in the West, caused me, during the past summer, to examine again the old areas in part, especially along the eastern slope of the Rocky Mountains in Colorado. The principal object I had in view was to determine as carefully as possible the stratigraphical relations of the coal-strata with the purely marine beds below. During the summer, I traced, with much care, the junction of these groups from Cañon City northward to Cheyenne on the Union Pacific Railroad, and thence along the railroad westward to Green River. As the largest development of the Lignitic group occurs in the vicinity of the railroad in Western Wyoming and Eastern Utah, it seemed important that this region should receive as much attention as possible.

We may state here in general terms that along the eastern base of the Rocky Mountains in Colorado, from the Raton Hills north to Cheyenne, there are no strictly marine coal-beds, and it is probable that they are all of brackish-water origin. As the entire thickness of this group in Eastern Colorado is estimated at about 3,000 feet, some of the upper beds may yet be found to contain well-marked fresh-water shells, but up to this time none have been reported as known from this entire area. The brackish-water shells have come for the most part from the lower beds.

We may consider for a moment the relations of the Cañon City group to the underlying Cretaceous series. We find near the base of the mountains, near Cañon City, on the Arkansas River, a fine development of the entire series of the Cretaceous, from the Dakota group to the summit of the Fox Hills group. No. 3, or the Niobrara group, is especially well shown in the uplifted ridges near the base of the mountains around Cañon City, and along the Arkansas River between Cañon City and Pueblo. For a distance of about ten miles below Cañon City, on the river, Nos. 4 and 5 are quite distinct; No. 4, composed of dark shaly clay, gradually passing up into a yellow arenaceous clay, and finally a laminated sandstone and clay to the lower sandstones of the coal group. If we follow up the dry beds of the little branches which lead into the Arkansas River from the coal area, we can note very distinctly the gradual change in the character of the sediments, showing the approach of shallow water and dry land. There are about 300 feet of the peculiar laminated sands, clays, and sandstones, largely concretionary, sometimes with layers of massive sandstone 15 to 30 feet thick, then thinning out or disappearing altogether, and a loose arenaceous clay taking their place. On this intermediate series of strata, an irregular bed of sandstone rests, varying from 50 to 200 feet in thickness, which we regard as the lowest bed of the Lignitic group. In this sandstone are quite abundant vegetable forms, and at different localities one to three thin seams of coal. Immediately over this sandstone occurs the best workable bed of coal yet known in this basin. This lower sandstone may be regarded as the horizon between the coal group and the Cretaceous from Raton Hills far north to Denver and probably farther. In the laminated sandstones and arenaceous clay below the lower sandstone of the coal group for 200 to 300 feet, I searched in vain for any trace of organic remains. Mr. J. N. Clark, a mining-engineer, for several years in charge of the coal interests of the Denver and Rio Grande Railroad, informed me that he had examined the entire country from Cañon City to the Raton Hills, and that he had never found a marine fossil within 200 feet of the first coal-bed. No fossils but plants have yet been found in the Cañon City group.

The Raton Hills come within the area assigned to Dr. F. M. Endlich, assistant geologist, for geological examinations during the season of 1875, and I requested him to give special attention to the relations of the coal-strata to the underlying beds. He reports an unconformability extending along the base of the mountains for many miles. This fact has not, to my knowledge, been previously observed. He says:—

"Underlying the coal-bearing strata, we find older formations, the youngest of which is the Cretaceous. As the divisions of this formation differ widely from those observed farther north, and a discussion thereof would be out of place here, I will merely state that I regard these strata as Cretaceous, in which I have found unmistakable invertebrate fossils which are acknowledged to belong to that geological period. Overlying these strata unconformably, although the unconformability is very much obscured at many places, the coal-bearing series of sandstones and shales begins. About 500 feet below the lowest coal-bed, I found the highest Cretaceous fossils. All the intermediate strata yielded no paleontological evidence whatever. A number of coal-beds, varying in thickness in different localities, occur, separated from each other by sandstones and shales. At Trinidad, the Lignitic, or coal-bearing group, reaches a thickness of about 2,600 feet, containing a large number of coal-beds and seams. As the development of the formation is very typical at that locality, I have designated it as the 'Trinidad Lignitic group.'

"Taking into consideration the stratigraphical relation, the absence of fossils that might weaken this evidence, and the observations made upon the parallel group farther west, as well as its sharply-defined characteristics, I have come to the conclusion that it certainly cannot correctly be classed with the Cretaceous formation. As I am not supplied with sufficient proof, based upon paleontological evidence, to regard the Lignitic group as being of Tertiary age, I assign to it an intermediate position, between Cretaceous and Tertiary, showing, however, more affinities to the latter than to the former."

The Lignitic group is entirely absent from the Arkansas River north to Colorado Springs. Passing eastward over the rolling plain from Colorado Springs, we gradually rise about 800 feet within a distance of nine miles. The country is underlaid with Nos. 4 and 5. At one locality, the characteristic fossils of No. 5 are very abundant and of considerable variety. The usual calcareous concretions are scattered thickly over the surface, which, when broken, reveal an abundance of *Baculites ovatus; Inoceramus*, several species; *Scaphites Conradi; S. Cheyennsis;* and many others peculiar to No. 5, and some that are found abundant in No. 4. From No. 5 there is a barren interval of 300 to 400 feet, very similar to that at Cañon City. In the upper portion of these laminated and rusty-brown concretionary sandstones, there is an abundance of impressions of sea-weeds, especially the *Halymenites major* of Lesquereux. The changes in the physical conditions, during this period of the deposition of the sediments, are admirably well shown by the different layers of the upper portion of the Fox Hills group up to the lower sandstones of the Lignitic.

The next most favorable locality for examination is near Platteville, on the Denver Pacific Railroad, about forty miles north of Denver. We have studied with much care the entire area embraced in the drainage of the Big and Little Thompson Creeks, Cache-à-la-Poudre, &c., so that it is hardly possible we can have been mistaken in our conclusions. On the west side of the South Platte River, opposite Fort Saint Vrain, are some rather high bluff hills, composed of the Upper Fox Hills group entirely. Here is an abundance of well-marked Cretaceous fossils, some of which have a wide geographical distribution, and are characteristic of the entire Fox Hills group, but which as a whole are peculiar and have not been known to occur previously in any other locality, except at the mouth of the Judith, on the Upper Missouri River. The entire mass of rocks in this region and on the Cache-à-la-Poudre show plainly the gradual approach from sediments deposited in deep, quiet waters to those laid down in shallow and turbulent seas. The shells in the Upper Fox Hills group were for the most part carried into eddies or restricted depressions, where they are found now, much broken and worn. There is no particular horizon in the group where the fossils may be found; but here and there a layer, from an inch to a foot in thickness and only a few feet in horizontal extent, is almost entirely made up of the shells. Of the fossils found together in the same beds *Nucula cancellata*, *N. planimarginata*, *Mactra Warrenana*, *M. formosa*, *Cardium speciosum*, *Tancredia Americana* are most abundant. A species of Ammonite, *A. lobatus*, which has a very extended vertical range in this group, is one of the last to disappear. It is found at this locality near the summit of the group. About five miles to the west of this point, on the opposte or east side of the South Platte, several shafts have been sunk in search of coal. The interval is mostly the alluvial bottom of the river, and therefore all the basis-rocks are concealed, but in this interval there were originally, without doubt, from one to two hundred feet of irregular layers of sand, sandstone, &c., probably barren of fossils. At any rate, the bed of sandstone, usually called the fucoidal sandstone, which usually lies at the basis of the Lignitic group, is wanting, or is obscured. The bed of coal, 2½ feet thick, was reached 52 feet below the surface. No fossils were found; but 300 yards southeast of the coal-shaft, the same parties sunk a second shaft, with the following results:

	Ft.	In.
1. Yellow sand and clay	42	0
2. Indurated clay or soapstone, with three inches of charred material, called "smut" by the miners	2	0
3. Clay	4	0
4. A layer of shells, *Anomia*, *Corbicula*, &c	3	6
5. Clay	0	6
6. Brown sand	1	6
7. Yellow and gray sandstone	10	..
8. Clay or soapstone	2	..
9. Coal	2	6
10. Clay-shale	0	4
11. Fine gray arenaceous clay	2	0
12. Clay near coal		

At a depth of 48 feet, the shaft passed through a bed of shells 3½ feet thick, with just clay enough to hold them loosely together. Two species were identical with fossils previously found by me in the clay, over a bed of coal, at Hallville, on the Union Pacific Railroad. That this bed of shells is above the marine sediments, and in brackish deposits, is evident. Nowhere has there been a strictly marine fossil discovered above or very near the lowest seam of coal.

About nine miles southeast of Cheyenne, there is a bed of coal, near the base of the Lignitic group, just over which, is a bed of oyster-shells three or four feet in thickness. The brackish character of the sediments of the lower portion of the Lignitic group is universal from British America, on the eastern slope of the Rocky Mountains, to New Mexico Near latitude 41°, a few miles south of the Union Pacific Railroad, on the east base of the mountains, the Lignitic group passes beneath the more modern White River group, and re-appears to the northward, about the line of parallel 43°. By examining the two geological maps, which I have long since published, the connection of the Colorado Lignitic with that of the Northwest will be at once apparent. It is not necessary to prolong these notes in this place, as the details of this subject have already been published in previous reports or will be fully elaborated hereafter. It re-mains now to deduce the following conclusions:—

1st. So far as Eastern Colorado is concerned, extending from Raton Hills to Cheyenne, we have no knowledge of any but brackish-water deposits of the age of the Lignitic group. Not a species of exclusively marine invertebrata passes above the lowest bed of coal. The sea-weed *Halymenites* is found in the Upper Fox Hills group and in the Lower Lignitic, but no special importance can be attached to this form as a test of the age of any group.

2d. It is evident that in many localities, and possibly throughout Eastern Colorado, a considerable portion of the Upper Fox Hills group is wanting. Sometimes the Lignitic group is deposited on No. 4 or No. 3 Cretaceous. Therefore, there is undoubtedly a conformable interrupted sequence; in other words, while the Lignitic group appears to conform to the underlying beds, there really are wanting hundreds, and perhaps thousands, of feet of strata which at some other locality in the West may exist.

3d. The fact that not a single form of animal or vegetable remains of strictly marine origin passes above the well-marked Cretaceous or Fox Hills group into the Lignitic, shows clearly that there is here a most important time-boundary; that not only stratigraphically, but biologically, one great epoch ends and another commences, each of which is, in every respect, distinct from the other.

4th. Inasmuch as the evidence is clear that the animal and vegetable forms below the base of the Lignitic group are strictly characteristic of the Cretaceous epoch, while in the Lignitic above, the vegetable life, with its great variety of forms, is regarded by our best authority, Professor Lesquereux, as purely Tertiary, and inasmuch as not one characteristic Cretaceous invertebrate has been found above the lowest bed of coal, but all have decided relations to Tertiary forms, we think we are warranted in regarding the Lignitic group of Eastern Colorado as of Eocene age.

In regard to the great coal-deposits of the interior of the continent, I desire to make some explanations in connection with the very valuable paper of Professor Lesquereux, which precedes this. During the past season, while endeavoring to gather materials to aid in settling the vexed problem of the age of these coal-deposits, after having examined with as much care as the time would permit the line of junction in Eastern Colorado, I spent some days along the Union Pacific Railroad as far as the station at Green River. Having studied the geology of this portion of the West from Cheyenne to Great Salt Lake more or less since 1868, I became convinced that the region where this problem is to be settled lies in the interior of the West, in Western Wyoming and Eastern Utah, and so stated in my annual report for 1873.* It is here that the continuity will be found to be more complete than in any other portion of the West.

In Bulletin No. 2, first series, I gave a brief account of my investigations of the Lignitic group and the reasons that led me to consider it entirely of Tertiary age. Having explored it for over twenty years in the Northwest, where it is nearly all of fresh-water origin, having traced it with much care from latitude 49° southward to New Mexico, through nearly twelve degrees of latitude, and over an area of from one hundred to one hundred and fifty thousand square miles, where the evidence, either directly or indirectly, leaned to the Tertiary age of the group, I was led to the opinion that it formed a separate group, which was brackish-water at base and gradually passed up without interruption into the beds of purely fresh-water origin. Wherever fossil plants were discovered to any extent in its southern extension, species were identified as the same with those so abundant on the Upper Missouri. During the summer of 1868, I made a careful exploration of the coal-beds at Coalville, Utah, and at Bear River on the Union Pacific Railroad, when I saw for the first time the unmistakable proof that the coal-beds extended down into the Cretaceous series. At Bear River, near the west line of Wyoming, there was an abundance of well-marked Cretaceous fossils above and below the most important beds of coal. At Coalville, the workable bed of coal seemed to be far down into the Cretaceous. In the Proceedings of the American Philosophical Society at Philadelphia, February 19, 1869, page 48, I published a brief account of my examinations.

As far back as 1853, I had known of the existence of a seam of coal in the Dakota group, and from time to time traces have been found even in the Fort Benton group above; but that coal-beds extended all the way from the Jurassic through all the divisions of the Cretaceous, up to the summit of the Lignitic group, was not known to me. The discoveries of various geologists in the interior of the continent, especially in New Mexico, Arizona, and Utah, show this to be the case. Mr. Holmes and Dr. Endlich, assistant geologists with this survey, have found in Southern and Southeastern Colorado, during the past season, heavy beds of coal all through the Cretaceous groups from the base up. These coal-beds were observed during the summer of 1874 by members of the survey near the boundary-lines between Colorado, New Mexico, and Arizona, with an abundance of Cretaceous fossils above and below the coal-beds.

In Bulletin No. 2, first series, dated April, 9, 1874, I made this statement: — "As we go southward into Southern Utah, New Mexico, and Arizona, the greater portion of the coal-beds are in rocks of undoubted Cretaceous age. It seems conclusive therefore that the Lignitic group began in the Cretaceous period in the marine seas, and continued on upward, through the brackish-water times, into the purely fresh-water deposits." It is plain, therefore, that much of the difference of opinion about these deposits among field geologists is like the story of the shield. Those who have worked from the south and southwest toward the north have been thoroughly impressed with the Cretaceous age of these beds, while those who have studied them from the north and northwest toward the interior basin, received their first impressions that they were of Tertiary age. We now see that, taking a view of the entire West, the coal does not seem to be confined to any period, but even extends down into the Jurassic. Dr. Newberry, as far back as 1859, discovered coal in beds of undoubtedly Jurassic age in Arizona, as his section of the strata near the old Moquis villages would indicate.

---

* See Annual Report for 1873, page 26.

If it is true that, taking into view the entire Lignitic area of our Western Territories, the coal-beds are continuous in every division, from the Jurassic to the summit of the Upper Lignitic, we might make this general division: 1st. Lower Lignitic group, including all the Lignitic deposits of marine origin; 2d. Middle Lignitic, embracing all deposits of brackish-water origin; 3d. Upper Lignitic, including all beds of purely fresh-water origin. In my opinion, the first division would include all beds to the summit of the true Cretaceous; the Middle Lignitic embraces my Transition series, or, if they are not admitted by geologists, I would insist upon their Lower Tertiary age. The Upper Lignitic, or fresh-water deposits, are of unquestioned Tertiary age. The details upon which these opinions are founded have been printed in my former reports, and cannot be repeated here without rendering this article too long.

On the west side of the Laramie Mountains, in the Laramie Plains, the Lignitic group re-appears to the westward. It is well shown at Rock Creek, on the east side of the Medicine Bow range, and is again well developed at Carbon, on the Union Pacific Railroad, where the coal has been very extensively wrought. Tracing the underlying formations from the west base of the Laramie range westward, across the plains, we find the full series of the Cretaceous groups gradually overlapping each other, and, before reaching Rock Creek, the lower beds of the Lignitic group extending over the Cretaceous beds, and corresponding with the same group on the east side of the Laramie Mountains.

The lithological characters, the fossils, and the relations of the group to the main beds below are so similar that I have inferred that all these beds once extended without interruption across the area now occupied by the mountain-range, and I still believe this generalization to be true. It is quite possible that some of the loftier ranges, as those of which Long's Peak and Pike's Peak form a part, were outlined far back in the past; but many of the minor ranges were undoubtedly elevated at a comparatively modern period.

As we proceed westward, there seems to have been an enormous thickening of the sediments, particularly during the Cretaceous and Tertiary periods. Commencing near the point where the Union Pacific Railroad crosses the North Platte, or about meridian of 107°, far west and south into the great interior basin, the aggregate thickness of the Cretaceous and Upper Lignitic (not including the fresh-water basins) must be at least 12,000 feet. As we reach the interior basin, all the formations known in that region have attained an enormous thickness, so that Mr. Clarence King regards the aggregate thickness of the sedimentary rocks in Utah at 56,000 feet; while in the immediate vicinity of the eastern division of the Rocky Mountains, the entire thickness of the sedimentary deposits cannot be one-third that amount. It is in the immediate valley of the Colorado, in Western New Mexico and Arizona, in the great basin between the Sierra and the Wasatch Mountains, where the principal thickening of these formations occurs. In such cases, their external characters change much, and the variety and quantity of the organic remains diminish to a great extent. Coarse conglomerates and sandstones may be said to characterize to a marked degree the beds from the lowest Silurian to the summit of the Cretaceous. In the Northwest, the Cretaceous series have been separated into five well-marked groups, made up mostly of sediments deposited in quiet waters, containing in various localities an astonishing quantity as well as a great variety of beautifully-preserved fossils. No portion of our present seas can have a greater variety or abundance of molluscous forms than are now exposed in long belts, or zones, across the Cretaceous area on the Upper Missouri; but, as we advance southward from the Upper Missouri, the typical characters of the Cretaceous divisions are gradually lost, so that in Colorado they are not well defined. In the interior basin, they are not well defined, and, had they been studied to any extent there, previous to their examination on the Upper Missouri, it is doubtful if any other classification than Upper, Middle and Lower Cretaceous would have been given.

Between Rock Springs and Salt Wells stations, on the Union Pacific Railroad, there is an interesting anticlinal valley that may aid in throwing some light on the structure of this region. This anticlinal was first noticed and described by me in my Annual Report for 1870, page 171. I have examined it several times since, but have had no opportunity of following this anticlinal north and south of the railroad. In this way, the problem could be solved; for to the west of this anticlinal valley there is a series of the coal group from the well-defined Cretaceous up to the Green River group, while to the east the series can be studied to the summit of the Washakie group. In the anticlinal valley about Salt Wells station, and west of it, the characteristic clays of No. 4 Cretaceous are well shown, and reach a thickness of at least three hundred feet. Tracing this bed upward through the gradual changes to the sands and laminated sandstones of No. 5, I found, immediately beneath the laminated sandstone, numerous rusty calcareous concretions, full of fossils, quite characteristic of Nos. 4 and 5, *Baculites*, *Scaphites*, and *Inoceramus*. Having thus fixed a horizon, I endeavored to follow it up. Looking toward the west from Salt Wells station, a long series of bluffs can be seen on either side, composed of the shales of No. 4, holding so far as the eye can determine a horizontal position; but facing to the east, on either hand far south and north, a series of high, pointed bluffs extend, as far as the eye can reach, underlaid by No. 4, but capped with No. 5, and inclining about northeast at an angle of 5° to 15°, generally with an average dip of 10° to 12°. This inclination continues far eastward until the marine and brackish-water beds pass beneath the fresh-water strata of the Washakie, near Bitter Creek station. Above No. 4, there are about twelve hundred feet of laminated sandstones and arenaceous clays; the layers of sandstone becoming thicker and more massive toward the summit. This group undoubtedly represents No. 5, greatly thickened and somewhat changed in its external features. Above No. 5, and distinctly marked, is an extensive group of irregular-bedded and somewhat variegated sandstones, with intervals of sand and clay, mostly yellow, gray, and brown in color, extending to Point of Rocks. The entire series I estimated at about one thousand feet in thickness; but it would have required a more extended examination north and south of the road to have determined this with precision. Above and below Point of Rocks station, there is a thick bed of grayish-brown sandstone, which at once arrests the eye from its remarkable structure. It is shown along the railroad east and west of Point of Rocks station for several miles, is very variable in thickness, sometimes reaching 250 feet, and forming a massive though rugged bluff wall. The proofs of deposition in turbulent waters are most remarkable, and the sediments are quite variable, though seldom so coarse as to become a conglomerate, varying from a rather fine sandstone to a pudding-stone. In this bed of sandstone are many irregular seams of indurated clay, sometimes simply filling small pockets or thin seams, extending only a few feet horizontally. It was in one of these seams of clay, about four feet thick, near the summit of the bed of sandstone, that a portion of the plants described in the preceding paper by Mr. Lesquereux were found. This sandstone appears to hold a position beneath all the workable beds of coal in this region, and from its thickness and massiveness forms a marked horizon. It is full of holes, cavities in some instances so large as to be called caves, worn out by the water which has trickled down from the top, the soft clay portions washing out most readily, so that the face of the rocks is often very rugged, presenting a most fantastic appearance. Sometimes the rock is literally honey-combed. The layers of deposition are so irregular that a mass in the center of the bed of sandstone, twenty or thirty feet thick in the middle, tapers to a point at each end within a horizontal distance of one hundred feet. Immediately above this sandstone at this locality are several beds of coal, four to six feet in thickness, and above and below these beds of coal are great quantities of oysters of several varieties and a species of *Corbicula*. It will be observed that everywhere the genus *Ostrea*, and in many instances *Anomia*, extend up into the brackish-water beds, and that even on the Upper Missouri, where these Lignitic beds were first discovered and pronounced to be of Miocene age, *Ostrea* and other brackish-water forms of *Mollusca* were found in the lowest strata. The group of plants described by Lesquereux from this sandstone are, so far as I know, from the lowest horizon in the series in which plants have been found up to this time. As Lesquereux remarks, the plants must represent a horizon very near the true Cretaceous beds, inasmuch as several of the species have strong Cretaceous affinities. At Rock Springs not a plant was found by me, and I cannot not ascertain that any one else has observed any at this locality. A species of *Corbicula* was rather abundant in the clay over the workable bed of coal.

It is not my purpose to present any details of the season's work in these notes. They are intended to be rather explanatory of my former views and the views I hold at present in regard to the important problem—the age of the Lignitic group in the West. So far as sections are concerned, as well as a most careful and accurate study of the formations from Bitter Creek to Coalville, the very detailed and interesting reports of Mr. F. B. Meek and H. M. Bannister in the Annual Report of the Survey for 1872 may be consulted.

With our present knowledge, we may separate the Lignitic beds, above what is usually understood as the Cretaceous Fox Hills group, into three divisions: 1st. The strictly marine strata, like those bearing coal at Bear River and Coalville; 2d. The mixed or brackish-water beds; 3d. The purely fresh-water strata, of which the upper portion of the Lignitic group of the Northwest is an excellent example. The first group contains abundant well-marked Cretaceous forms; yet even in this division, the physical changes which we find at later date were foreshadowed by the mingling of a few brackish-water species. The genus *Inoceramus*, which has always been relied upon as strong proof of the Cretaceous age of beds in which it occurs, is found both at Bear River and Coalville in great abundance.

Reaching a certain horizon, we gradually approach a second group of beds, in which are found, in some localities, in seams varying from a few inches to several feet in thickness, made up almost entirely of different species of *Ostrea*, and mingled with them are a few well-known brackish-water forms. All the forms of *Mollusca* akin to those known in this group flourish in the brackish waters of our day.

Passing upwards, we gradually come to a great thickness of strata in which fresh-water Mollusks predominate. A careful study of the entire Upper Lignitic group from the bottom of the first division to the summit of the third, extended over the entire area of the West, would doubtless show no abrupt physical break in the series of molluscous life, but the marine and brackish-water forms gradually drop out of existence as the fresh waters slowly predominate, until only fresh-water forms are found. From the first appearance of the vegetable life, many forms appear which have a very extended vertical as well as horizontal range geographically. Now the question would arise as to where the line should be drawn between the Cretaceous and Tertiary formations. The stratigrapher may have much to do with this; for, if done at all, it must be drawn mostly on his testimony. That there may be faults or breaks in the series is quite possible, inasmuch as there must have been continued alternations or oscillations of land and water throughout 8,000 or 10,000 feet of strata, and, therefore, would even a slight unconformability be sufficient to decide the line of demarkation? It may be said that there are brackish-water strata in formations of all ages; but it must be recollected that the brackish-water strata in the Lignitic group are not restricted to a limited locality, but are as extensive as the formation itself. They extend from British America to New Mexico, and it is only in groups of Tertiary age that we have such widely-extended fresh-water deposits. I must insist, therefore, that my series of transition, or beds of passage, be acknowledged as having a real existence until some evidence is presented to the contrary. In all portions of the divisions mentioned above, we find, 1st, a gradual dropping-out of the strictly marine; 2d, the same gradual disappearance of the brackish-water forms. The third or fresh-water division will doubtless be regarded by all geologists as of Tertiary age.

In reply to the statement that the term "Lignitic" is not applicable to any one group, from the fact that coal is found in all the formations from the Jurassic to the summit of the Tertiary, I will say that I am well aware of that fact. In the Annual Report of the Survey for 1870, page 59, I mention the occurrence of several thin seams of lignite as occurring in the Green River group, on Henry's Fork. Great quantities of fresh-water shells were also found in close proximity. In the Washakie group, which extends along the railroad from near Separation to Bitter Creek, forming the divide of the continent, there are several beds of impure lignite. Many fresh-water shells occur in this group, similar or identical with those found at the base of the Green River group near the mouth of Henry's Fork. I have no doubt, therefore, that the Washakie group extends on westward across the anticlinal, re-appearing at Green River near the mouth of Henry's Fork from beneath the Green River group.

In the summer of 1870, I traced with considerable care the vast thickness of strata which are revealed from the junction of Henry's Fork northward along the west bank of Green River, from the Cretaceous through the Lignitic group, and the western extension of the Washakie group up to the Green River shales, and in the report of that year a full account is given. Up to this time I do not find occasion to modify, to any great extent, the opinions therein expressed.

Throughout the Lignitic group proper, that is, the portion occurring above the Fox Hills group, I have never found any true nonconformity. That there may be in some places an interrupted sequence in the beds is quite possible, and I am inclined to think the top of the thick bed of sandstone near Point of Rocks is an example. That there have been many oscillations of the surface, that it has been alternately above and below water many times, may be inferred from the numerous coal-beds. In the aggregate, there could hardly have been any marked interruption in the sequence of the deposition, even up to the summits of the highest Tertiary, though between the Lignitic group and the more modern Tertiaries, as the Washakie, Green River, and other fresh-water groups, there is at this time a true nonconformity. We may conclude that during the marine Lignitic, the mountain-ranges were slowly rising above the sea-level, yet there was an almost universal sea. During the middle, or brackish-water period, there were huge inland lakes, to which the salt seas had access, thus rendering them brackish, and still the general elevation of the crust went on. Still later, these inland lakes were cut off from marine waters, and the deposition of the sediments went on through countless ages, and the mountains continued rising, and these sediments were deposited against their sides as a shore-line. If we could look beneath the horizontal strata of the Washakie group between Separation and Bitter Creek, or under the Bridger and Green River groups along the immediate line of the railroad, we might find localities where the sequence of the beds is not interrupted, and yet, in the immediate vicinity of the mountain-ranges, as the Uintah, for example, the modern fresh-water Tertiaries rest unconformably on the older rocks. The Bridger and Green River groups jut up against the sides of the Uintah range with a very slight inclination. The White River group, on the east side of the Rocky Mountains, shows the same style of unconformability, never inclining more than 5° to 10°, even where the underlying Lignitic beds dip at a much greater angle.

So far as the geology of the Rocky Mountain region is concerned, the doctrine of the uninterrupted sequence of events is a most important one. If we were perfectly familiar with the structure of every portion of our earth's crust, it is probable that somewhere we should find an uninterrupted sequence in the deposition of sediments from the oldest known sedimentary rocks up through all epochs to the present time. We should then have such a unity in the fabric that we would be unable to decide where one age began and another ended; and the terms Silurian, Devonian, &c., would only appear as relics of the imperfect knowledge of the past. It is the highest aim of the geologist to obliterate, as far as possible, these lines of demarkation; and if, in the far western regions, we can remove all trace of any chasms between the Cretaceous and the Tertiary epochs, we have made an immense advance toward the completion of the geological fabric. Again, the evidence in regard to the age of the group, derived from the numerous vegetable remains, has been almost entirely ignored by some geologists as worthless, and great stress laid on that obtained from the vertebrates. With all due respect for their opinions, I am confident the reverse is the true state of the case, and that the vertebrates are of little value as tests of the age of these formations. We have shown how readily the change from purely marine waters to brackish and fresh waters would necessarily and did destroy all traces of marine invertebrate life; yet, according to Professor Cope, Cretaceous vertebrates continued far upward into the fresh-water portions of the true Lignitic group of the Northwest. Not a single species, however, seems to be identical with any found in other portions of the world; but the inference is drawn that they must be Cretaceous from their relationship. The vertebrates of the Lignitic period having great powers of locomotion, and being able to live on land as well as in the lakes and marshes of that time, and as we have shown that there was at no time any important catastrophe or physical changes sufficient to affect them, could well have prolonged their existence far up into the Lignitic group, carrying with them as an inheritance, their Cretaceous characters, so that the important statement of Professor Cope is founded in fact, that during this period a Cretaceous fauna was contemporaneous with a Tertiary flora, establishing an uninterrupted succession of life across what is regarded as one of the greatest breaks in geological time.

V. Fak. U.S.

[From the American Journal of Science and Arts, Vol. VII, April, 1874.]

ON THE LIGNITES AND PLANT-BEDS OF WESTERN AMERICA.

By J. S. NEWBERRY.

In the Geological Report of Prof. F. V. Hayden for 1872, Mr. Leo Lesquereux gives a comprehensive review of the fossil flora found associated with beds of lignite, in various localities through the western portion of our continent. The views advanced in this paper are so inconsistent with the facts observed by myself, that I venture to call in question the accuracy of some of them. By Mr. Lesquereux, much the greater part of the fossil plants found at the west are referred to the Eocene, whereas, to my certain knowledge, a considerable portion of the flora which he calls Eocene is Cretaceous, and another considerable portion is of Miocene age. This question will be discussed in a report on the fossil plants of New Mexico, Dakotah, Oregon, etc., which I am preparing for Prof. Hayden, and I will now only allude to some of the facts which are incompatible with Mr. Lesquereux's views.

The earliest and best known of the plant-beds of the far west are those of the region of the plains, in Nebraska, Kansas and the Indian Territory, of which those of Black Bird Hill, Fort Harker, Walnut Creek and Whetstone Creek may be taken as examples. These were at first pronounced by Prof. Heer to be Miocene, and in this view he was defended by Mr. Lesquereux, while I asserted that they were Cretaceous.* It is now universally conceded that the latter view was correct. From this horizon, we have obtained a large number of fossil plants, and this, the first angiospermous flora known, has proved to be of great richness and interest. It has, however, passed out of discussion, and requires no further notice here.

During my explorations of New Mexico and Arizona, I found beds of lignite at various localities; those of the San Juan, for example, attaining a thickness of from thirty to fifty feet. With these lignites are many fossil plants. Dr. Hayden, who in 1869 made a reconnaissance as far south as Santa Fe, touching these plant-beds on Galisteo Creek, referred them to the Tertiary. Following him, Mr. Lesquereux has reported all the New Mexican lignite and plant-beds to be of Eocene Tertiary age. Having spent nearly two years in this region, constantly occupied in the study of its geology, I feel authorized to state that all the lignite beds yet known in New Mexico are unmistakably of Cretaceous age. Fossil plants are found at several different horizons in the Cretaceous, but none whatever in the Tertiary. In fact, the only Tertiary strata known in New Mexico are the chalky fresh-water marls deposited in basins of the present topography, and without fossil plants.

---

* This Journal, vol. xxviii, p. 85; xxix, pp. 208, 434.

The lignites of Colorado, which are so largely developed in the Raton Mountains, at Trinidad, Golden, Marshall's, etc., have been studied by Mr. Lesquereux in place, and by him they, with their associated plant-beds, are regarded as constituting typical examples of our American Eocene deposits. As I have not visited that portion of Colorado where this great lignite formation is exposed, I will not venture to deny the truth of the conclusions arrived at by Mr. Lesquereux. I may say, however—1st, That the flora of these Colorado lignite-beds has almost nothing in common with that of the European Eocene. Its botanical aspect is certainly entirely different, and, in my judgment, not a single species and scarcely any genera are found in both. 2d, That the tuberculated fucoid (*Halymenites*), considered by Mr. Lesquereux as diagnostic of the Eocene, is in New Mexico the most characteristic fossil plant of the *Cretaceous* sandstones. 3d, That Profs. Meek, Marsh, Cope and Stevenson, guided by the molluscous and vertebrate remains found in the Colorado lignite deposits, consider them Upper Cretaceous.

The age of the lignites of Wyoming and Utah—of Carbon Station, Rock Springs, Coalville, Hallville, Evanston, Bear River, &c.,—has been discussed at length by Messrs. King, Emmons, Meek and Cope. While it is admitted by all that there are wide-spread Tertiary deposits in Wyoming and Utah, and some of them contain lignite and fossil plants, it is claimed and apparently proved, by the gentlemen whose names are cited above, that the lignites of the localities named are Cretaceous.*

In regard to the Bitter Creek lignites, Mr. Meek shows that the evidence, if not conflicting, is at least indecisive of their age.

The strata of Wyoming, which contain the newly discovered and wonderful vertebrate fauna described by Profs. Leidy, Marsh and Cope, are thought by these gentlemen to be clearly Eocene. But, though so rich in animal remains, they contain few plants, and these throw little light on the discussion. The Green River plant-beds are placed by Mr. Lesquereux in the Miocene; but a small group of plants which I have from these beds includes palms (*Manicaria*) and other plants not found elsewhere in the Miocene of America. Mr. Lesquereux is disposed to regard palms as diagnostic of Eocene, but they are common enough in the Miocene of Europe, and they should have grown in Wyoming when the luxuriant Miocene flora covered Alaska and Greenland.

---

* A very comprehensive review of the question is given by Mr. F. B. Meek in the chapter of Prof. Hayden's Report which succeeds the paper of Mr. Lesquereux.

From the great lignite basin of the Upper Missouri, a large number of fossil plants have been brought to me by Prof. Hayden, the Sully expedition and others. Many of these have been already described, and the flora which they represent I have pronounced Miocene.* In the review to which I have alluded, Mr. Lesquereux refers all the plants from the Upper Missouri lignite-beds to the Lower Eocene. This conclusion I am unable to accept, from the fact that the general facies of the Missouri lignite-flora is altogether unlike that of the European Eocene, and it is identified with the Miocene flora of Arctic America, Iceland, the Hebrides and Central Europe, by most of its genera and by a considerable number of well-marked identical species. It also contains some species which are living at the present day. Among these latter may be mentioned our deciduous cypress (*Taxodium distichum*) and the sensitive fern (*Onoclea sensibilis*). This fern also occurs in Greenland, and is that described by Edward Forbes, from the plant-beds of the Island of Mull, under the name of *Filicites Hebridicus.* Among the plants common to the Upper Missouri lignite-beds and other well known Miocene deposits, are *Corylus McQuarrii* Forbes, *Glyptostrobus Europæus* Ung., *Sequoia Nordenskioldi* Heer, *Carya Antiquorum* Newb., (=*Juglans nigella* Heer), *Populus cordata* Newb., (=*P. Zaddachi* Heer), *Taxites occidentalis* Newb., *Thuia interrupta* Newb., etc.

The coals and fossil plants of Vancouver's Island are stated by Mr. Lesquereux to be of Tertiary age; but the evidence that they are Cretaceous is overwhelming. Some of the species found in the locality were at first supposed by Prof. Heer and Mr. Lesquereux to be identical with European Miocene species, but we now know that this identification was made upon insufficent evidence. Among the fossil plants which I have seen from Vancouver's Island, there is only one which I can certainly identify with a species found elsewhere, and that is *Sequoia Reichenbachi*, which occurs in numerous localities in the Cretaceous of Europe and in the Arctic. The Cretaceous age of the Vancouver coal was known to me as early as 1858, when I received the first collections made there by the late Mr. George Gibbs, and it was demonstrated in the paper on the fossils collected by him, published in the Proceedings of the Boston Natural History Society, in 1863. Interstratified with and overlying the beds of coal at Nanaimo, are strata containing great numbers of well marked Cretaceous mollusks, *Ammonites*, *Baculites*, *Inoceramus*, etc. With our present knowledge of paleontology, very few geologists would consider the question of the age of strata which contain these genera open to discussion.

---

* "Our Later Extinct Floras"—Annals Lyc. Nat. Hist., N. Y., vol. ix, 1868.

The plant-beds of Birch Bay, from which collections were made by Prof. Dana, when connected with the U. S. Exploring Expedition; those of Burrard Inlet, and those of Eastern Oregon, from which such extensive collections have been made by the Rev. Thomas Condon, are, in my judgment, all Miocene. The same may be said of those of Alaska and McKenzie's River; at least, in all these, as well as in those of the Upper Missouri, we find species which recur in Greenland, Iceland and continental Europe, in what has been universally called the Miocene flora.

The Eocene flora of Europe, as exhibited in the Island of Sheppey, at Monte Bolca, etc., has a distinctly tropical and Indo-Australian character; and we must say that, up to the present time, no similar group of plants has been found in America. In a botanical point of view, therefore, we are quite safe in the statement that the Eocene flora has not yet been recognized in this country. Looking at the question, however, from a geological stand-point, it assumes a somewhat different aspect. It is certain that we find on this continent Tertiary deposits which correspond in position with the Eocene of the Old World, and these contain many Eocene mollusks. If, now, fossil plants were found associated with these, we should be compelled to regard them as forming an Eocene flora, whatever their botanical character might be; just as our Cretaceous flora is none the less Cretaceous, though somewhat more closely allied to the Tertiary flora than are the plants found in the Cretaceous of Europe. Yet we find, with our Cretaceous plants, great numbers of well marked Cretaceous animal fossils, and these have very properly outweighed the modern facies of our Cretaceous flora. But have we found in or with the plants, supposed by Mr. Lesquereux to form our Eocene flora, any satisfactory internal or external evidence of their Eocene age—that is, have we among them any unmistakable Eocene plants or associated with them any unmistakable Eocene mollusks or vertebrates? So far as regards the central and western portions of the continent, I should say we had not. In the plant-beds which I have regarded as Miocene, the whole aspect of the flora is that of the Miocene of Europe, and it contains a very considerable number of well marked Miocene species, and not one, so far as I know, which deserves to be called Eocene. The lignites and plant-beds of New Mexico which I have called Cretaceous, but which are referred by Mr. Lesquereux to the Tertiary, are for the most part derived from the lower portions of our Cretaceous series, and are overlaid by many hundred feet of strata unquestionably Cretaceous, in which all the typical forms of Cretaceous animal life are abundantly represented. Whether the great lignite deposits of Colorado should be considered Tertiary or Cretaceous, it is perhaps not yet possible to decide; but, in the absence of any distinctive or unmistakable Eocene plants, if the strata which contain them shall be found to include vertebrates or mollusks which have a decidedly Mesozoic character, we shall be compelled to include them in the Cretaceous system. Mr. Lesquereux has met the statements of Profs. Meek, Cope and Marsh, that Cretaceous mollusks had been found in and overlying the Colorado lignite deposits, by pointing to his 250 species of fossil plants, claiming that they far outweigh the testimony of the animal remains. In fact, however, these fossil plants have very little bearing on the question. They are probably all distinct from European Cretaceous and Eocene species, and the genera to which they are supposed to belong afford only negative evidence of the strata that contain them.*

It is by no means insisted that we must find in America the plants of the European Eocene, before we can be said to have an Eocene flora, since, during the Eocene period, the physical geography of Europe was such as to give it a very different flora from any that *ever* grew on the North American continent. During the deposition of the Eocene strata, the great mountain barrier which extends from the Bay of Biscay to the China sea—formed by the Pyrenees, Alps, Carpathians, Caucasus and Himalayas—existed, if at all, only in embryo. The Mediterranean communicated with the Indian Ocean, the south shore of Europe was washed by a tropical sea, and the land was covered with a sub-tropical, Indo-Australian flora. When, however, the great mountain barrier, to which I have referred, was raised, these Austral influences were cut off, the climate of Europe was rendered temperate, and the surface was gradually covered with a temperate flora which, because it included a large number of American plants, *Liriodendron*, *Liquidambar*, *Magnolia*, &c., we may call the *American* flora. This was the flora of the Miocene, of which we have illustration in the fossil plants of Fort Union in Dacotah, Greenland, Iceland, Oeningen, &c. This flora seems to have possessed Europe up to the advent of the ice period. By the advancing cold, it was driven to the shores of the Mediterranean, and there exterminated. When the glaciers were withdrawn, and a milder climate supervened, Asiatic plants seem to have come in and taken possession of the vacant territory. In our country, the history of our vegetation shows no such vicissitudes. From the close of the Triassic period to the present time, our continent has apparently been occupied by plants which form an unbroken succession. The north and south reach of our continent has given to the flora a connected belt of territory extending from Central America to the Arctic Sea, over which it could march and countermarch as impelled by alternations of temperature. We need not expect, therefore, to find here any such contrast between the flora of the Eocene and Miocene as is recorded in the Tertiary strata of Europe. Still we have reason to believe that, during the Eocene period, our climate was warmer than during the Miocene, and we may expect to find, in the two floras of the Tertiary, differences of degree if not of kind. In the fruits of the Brandon lignites, in the Palm (*Calamopsis*) and Cinnamon of the Mississippi Tertiaries, and in the palm (*Manicaria*) of the Green River beds, we have, perhaps, some indication of this elevation of temperature and some traces of an Eocene flora. Whatever plants are found with *Zeuglodon cetoides*, *Cardita planicosta*, *Orbitoides Mantelli*, etc., etc., we must accept as Eocene, even should they have no intrinsic Eocene characteristic. So in regard to our Cretaceous flora. While it is altogether new, its varied character and modern aspect simply gives us a new revelation in regard to the vegetation of the Cretaceous world; for, while the fauna of that world contains *Ammonites*, *Baculites*, *Inoceramus*, &c., we are forced to call it Cretaceous. It is not *impossible* that the physical conditions of our continent may have remained so constant that the Cretaceous age faded gradually into the Tertiary. It is not *impossible*, therefore, that we may find some Cretaceous forms of life interlocking with those of the Tertiary age, but truth requires us to say that, up to the present time, *no such connecting links have been found.* The lignites of New Mexico are covered with thousands of feet of sediments, sometimes largely made up of the remains of all the typical Cretaceous forms of life. Possibly in Colorado, beyond the reach of the Cretaceous sea, or where the land was exposed by the retreat of that sea, the Cretaceous flora may have grown on and on into the Tertiary; but as yet we have no evidence of this. Above the lignite beds, a break in the stratification and a conglomerate (Echo Cañon conglomerate) mark the beginning of a new era. Without asserting that this new era was the Tertiary, and the one which had gone before was the Cretaceous, I feel justified in saying that such will probably prove to be the case; or, at least, that no evidence has been yet found which disproves it.

---

* It is an important fact, in this connection, that Lesquereux identifies a number of the species of plants of the Lignite beds with *Miocene* species of Europe. See the last volume of this Journal, page 448.—EDS.

To whatever conclusion, in regard to the age of the plant beds of the west, the facts may lead, when they are all gathered in, that result will be cheerfully accepted by every right-minded man. It is important, however, for the true progress of science, that no conclusion should be accepted until it is sustained by ample proof.

VI

Fqk. U.S.

AUTHOR'S EDITION.

DEPARTMENT OF THE INTERIOR.
UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY.
F. V. HAYDEN, U. S. Geologist-in-Charge.

JURA-TRIAS SECTION
OF
SOUTHEASTERN IDAHO AND WESTERN WYOMING.

BY

A. C. PEALE, M. D.

EXTRACTED FROM THE BULLETIN OF THE SURVEY, VOL. V, NO. 1.

WASHINGTON, February 28, 1879.

Art. VI.—Jura-Trias Section of Southeastern Idaho and Western Wyoming.

By A. C. Peale, M. D.

In connection with Paleontological Papers No. 9, published in this Bulletin (Art. V, pp. 105–117) by Dr. C. A. White, in which a number of new and specially interesting species of fossils are described, I have thought it may be both interesting and useful to give briefly a few notes on the section of the Jura-Trias of the region from which these organic remains were obtained.

The rocks under consideration are exposed in considerable areas in the district assigned me for examination during the field-season of 1877, especially between the Wyoming and Portneuf Ranges. The former is in longitude 110° 48′ and the latter in approximate longitude 112°.

The region thus indicated is one of complicated folds and great displacements, and the Jura-Trias rocks, with the conformably underlying Carboniferous, enter largely into the structure of the mountains; entire ranges, indeed, being carved from them.

The Triassic Red Beds are found on the summit and on the western slopes of the Wyoming Range, in the former occupying a broad synclinal depression, and in the latter dipping westward into the valley of John Day's River. An immense fault extends along the eastern front of the Wyoming Range, giving it a monoclinal structure at this place, and when we cross the fold, which forms the western side of the range, we find another similar fault along the eastern side of the Salt River Range, which is parallel to the Wyoming Range, and only from eight to ten miles west of it. These faults are several thousand feet in extent.

In the Salt River Range, the Jura-Trias rocks are found entering into the complicated folds that form its central portions.

Twenty-five miles farther west, we reach the Blackfoot Basin, in which the Jura-Trias forms a large portion of the surface, the ridges having a comparatively low elevation, and the folds not being so greatly eroded as in the higher mountains. It is in this locality that the interesting collection of fossils, described by Dr. White, was found, and to which his paper is confined. The following is the general section of the Jura-Trias, beginning at the top:

General Section of Jura-Trias in Southeastern Idaho and Western Wyoming.

JURA-TRIAS.	JURASSIC.	*Belemnites Beds.*	5. Red and gray shales with green sandstones and irregular greenish arenaceous limestones at the top. Thickness, 700 feet.
		Pentacrinus Beds.	4. Laminated limestones, blue at base, passing into gray at top, succeeded above by grayish, calcareous shales; many of the layers are probably arenaceous. Thickness, 800 feet.
	TRIASSIC?	*Red Beds.*	3. Red quartzitic sandstones with shaly arenaceous and calcareous layers at the base of the section. These are probably the equivalent of the typical "Red Beds" of the Eastern Rocky Mountains. Thickness, 1,000+ feet.
		Meekoceras Beds.	2. Alternations of reddish and greenish sandstones and arenaceous and calcareous shales with blue and gray limestones, generally laminated. Thickness, 3,000+ feet. These with No. 1 are the beds of the section given in Dr. White's paper (as that of locality No. 1). The beds are fossiliferous at four horizons, containing species of a new Triassic? genus named *Meekoceras* by Professor Hyatt, together with forms that have been heretofore regarded as of Jurassic age.
CARBONIFEROUS?			1. Massive grayish-blue limestone, overlaid by quartzite and dark blue laminated limestones. Thickness, 1,200+ feet.

The thicknesses in this section are estimated, and when the region is more thoroughly studied may have to be somewhat modified.

The fossils described in Dr. White's paper came from No. 2, which I have called the "Meekoceras Beds," from the new genus named by Professor Hyatt. They are the following:

Meekoceras aplanatum White.
Meekoceras mushbachanus White.
Meekoceras gracilitatis White.

Besides these, the following were obtained:

Arcestes? cirratus White.
Arcestes? sp.?
Arcestes? sp.?
Terebratula semisimplex White.
Terebratula augusta Hall and Whitfield?
Eumicrotis curta M. & H.
Aviculopecten idahoensis Meek.
Aviculopecten altus White.
Aviculopecten pealei White.
Gervillia sp.?

No. 3 yielded no fossils.

No. 4 yielded the following:

Pentacrinus asteriscus.
Camptonectes bellistriatus.
Trigonia sp.?
Myacites sp.?

From No. 5 I obtained:

Belemnites densus.
Aviculopecten idahoensis ?
Gryphæa sp. ?
Undetermined bivalves.

At no one point was the entire section, as given above, exposed. The evidence for the section is as follows:

Nos. 1 and 2 were determined by the section at and near Station 66, south of John Gray's Lake (section at locality No. 1 in Dr. White's paper).

Near Station 56 in the Salt River Range, about 28 miles east of Station 66, beds lithologically similar to those of No. 2 in the general section just given, and containing *Aviculopecten pealei* and *Gervillia*, were seen in position above limestones similar to those of No. 1, which here contained quantities of *Productus multistriatus*. On this ground I have referred No. 1 to the Carboniferous.

Above the arenaceous and calcareous bed (which correspond lithologically and paleontologically with No. 2 of the section) in the Salt River Range are the red sandstones (No. 3). They are also probably in place above the section of Station 66, as is evident from the following:

Descending the ridge leading southwest from Station 66, southwesterly dips are noted in the strata last seen (the upper ones of section at locality No. 1, White's paper). After passing through the timber, which conceals the remainder of the section, we come to red sandstones, in all respects like those of the Salt River Range, having a northeasterly dip. We have therefore crossed a synclinal.

These facts, therefore, appear to justify me in connecting the sections.

Nos. 4 and 5 are determined by sections made in John Day's Valley, where they rest conformably on the "Red Beds." The entire section is conformable. Above the "Belemnites Beds" is a quartzite followed by a series of shales and sandstones several thousand feet in thickness, which has been referred to the Cretaceous.

It is not my intention to enter into any paleontological discussion; but there are some points based on the paleontological contents of the section to which I wish to refer briefly.

Pentacrinus asteriscus was found at a number of localities, other than those of the section, throughout the district, and always in beds above the horizon of the Red Beds. The following were the associated fossils identified by Dr. White:

Camptonectes bellistriatus.
Ostrea strigulecula.
Trigonia sp. ?
Tancredia sp. ?
Modiola sp. ?

Myalina sp.?
Myacites sp.?
Neritina sp.?

Undetermined Conchifers and Gasteropods.

I believe the only instance in which *P. asteriscus* has been found associated with Triassic forms is the one mentioned in the Reports of the Fortieth Parallel Survey,* in which it is stated that it was found associated with what are regarded as unmistakable Alpine Trias fossils, and a *Spirifera*, a palæozoic type. Mr. Emmons says:† "It should be stated also that these disks of *Pentacrinus* found in the Dun Glen limestone vary somewhat from the type-specimens, and are all of larger size, reaching one-fourth of an inch in diameter, while those of Jurassic age scarcely reach one-fifth of an inch. Professor Whitfield suggests that the Dun Glen variety may possibly be a new species."

Eumicrotis curta was not found associated with *Pentacrinus* anywhere in our district, but at several localities where the section was obscure it was found with

Aviculopecten idahoensis,
Lingula brevirostris,
Myalina sp.?,
Myacites sp.?, and

several undetermined species of *Aviculopecten*.

The beds from which they were collected were above the "Red Beds," but I was unable to determine their relation to the "Pentacrinus Beds."

In other areas, *Eumicrotis curta* has been found associated with species of Jurassic aspect. In the areas surveyed by the Fortieth Parallel Survey, it occurs with

Belemnites,
Gryphæa.

Terebratula augusta Hall & Whitfield,‡ as Dr. White remarks, has been considered by the authors as a Jurassic species.

The Cephalopods (from No. 2 of the section described) by Professor White are, according to his identifications, unquestionably Triassic according to European standards, resembling certain Cephalopods of the Muschelkalk of Europe.

The only other Cephalopods from our Western Trias are those obtained by the Fortieth Parallel Survey from the Star Peak Group, which have been considered the faunal equivalents of the St. Cassian and Hallstadt beds of the Austrian Alps. The Star Peak Group is referred by King to the Upper Trias, and is supposed to correspond to the Upper Red Beds of the Eastern Seas (*Rocky Mountain Region, &c.*). If this be so, we may perhaps consider the "Meekoceras Beds" of the section as the equivalent of King's Koipato Group, which is below the Star Peak Group. The localities, however, are too widely separated, and too imperfectly known, as regards the one in my district, to attempt to correlate the two sections more definitely.

---

*Descriptive Geology, vol. ii, p. 711. Systematic Geology, vol. i, pp. 279, 280.

†Descriptive Geology, vol. ii, p. 711.

‡Report U. S. Geol. Expl. 40th Parallel, Systematic Geology, vol. i, p. 292.

We cannot be too cautious in predicating the age of these beds before a detailed study of the stratigraphy is made, and a careful paleontological examination of the whole region undertaken and completed.

The "Meekoceras Beds," when first seen by us, were referred to the Upper Division of the Carboniferous.

There are numerous circumstances that appear to indicate that in the Jura-Trias, as in other formations, we have at either end of the formation a plane of paleontological indefiniteness, as it may be called; and the probability is that in the immediate vicinity of the lines separating the formations the strata should be considered as transition series. When the deposition of sediments is continuous from one formation to another, it is not so strange, as Dr. White has frequently remarked, that forms of life should continue uninterruptedly from one to the other, and that we should find, as in New Mexico,* Triassic plants at the top of the Jura, and as in our district and many other localities Jurassic invertebrates near the base of the Trias, and as in Nevada palæozoic types in the Lower Mesozoic.

In predicating the age of any group of beds, the organic contents of all descriptions, *vertebrate*, *invertebrate*, and *vegetable*, should be considered.

With the accumulation of data, many of the points that are now obscure and doubtful will assume the certainty of facts.

Until we know more of the rocks under consideration, I shall retain the name Jura-Trias for the formation.

To recapitulate, the investigations of 1877 in Southeastern Idaho and Western Wyoming indicate—

1. The lithological separation of the Jura-Trias into three divisions,—the upper and lower calcareous, and the middle mainly silcieous.

2. The presence of Jurassic forms in the upper division, the absence of organic remains in the middle group, and the presence in the lower of Triassic types associated with what have heretofore been regarded as Jurassic species.

---

* See Report U. S. Geol. Surv. for 1875, 1876, pp. 84–87.

ic and
t Books
e by
'OOTE, M.D.
lmont Ave.,
lphia, Pa.

VII.

Figk. U.S.

R.P.

AUTHOR'S EDITION.

DEPARTMENT OF THE INTERIOR.
UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY.
F. V. HAYDEN, U. S. Geologist-in-Charge.

FOSSIL FORESTS OF THE VOLCANIC TERTIARY FORMATIONS OF THE YELLOWSTONE NATIONAL PARK.

BY

W. H. HOLMES.

EXTRACTED FROM THE BULLETIN OF THE SURVEY, VOL. V, NO. 1.

WASHINGTON, February 28, 1879.

Art. VII.—Fossil Forests of the Volcanic Tertiary Formations of the Yellowstone National Park.

By W. H. Holmes.

The prevalence of extraordinary volcanic activity throughout that part of the Tertiary age represented by the post-Cretaceous rocks of the Yellowstone region has given to them a most unique and interesting character. So destitute of animal remains are they, and so unlike the formations of the age in other parts of the Rocky Mountain region, that, notwithstanding the frequent visits of geologists, no divisions into sub-groups have been made, and no more definite appellation for the whole group has been found than the "*Volcanic Tertiary*"; this name, although so general, is singularly appropriate, and, in the absence of specific determinations, may be used to designate the entire group of Tertiary strata in the Park district.

It is not my intention in this brief notice to attempt the classification or correlation of these strata, but to give a brief account of some very remarkable features brought to light by last year's explorations.

In the valley of the East Fork of the Yellowstone River, where this peculiar group of rocks is typically developed, they have a thickness of upwards of 5,000 feet. The prevailing materials which enter into their composition are fragmentary volcanic products, which have been apparently redistributed by water, and now form breccias, conglomerates, and sandstones. It has been noticed by nearly all visitors that these strata contain a great abundance of silicified wood, and in a few cases trunks of trees *in situ* have been reported. The lowest observed occurrence of the strata of this group is in the valley of the main Yellowstone, between the first and second cañons, at an elevation of about 5,000 feet above the sea. They are also finely developed in the Gallatin Range to the west of this valley, and about the sources of Cañon and Boulder Creeks reach a thickness of between 3,000 and 4,000 feet. At a number of points covering this entire thickness, masses of silicified wood occur, and near the divide at the head of Boulder Creek silicified trunks, many feet in height, and of gigantic proportions, stand in the identical strata in which they grew, the crumbling conglomerates having withered away, leaving them standing upright along the steep slopes of the mountain. In general, these strata are horizontal. The bedding is often heavy, and in places not well marked; sub-aërial volcanic deposits apparently alternate to some extent with the sub-aqueous.

Three miles above the mouth of Gardiner's River, in similar strata, there are a number of silicified trunks *in situ*, most of which occur in a stratum of sandstone that lies directly upon the eroded surface of a series of mica-schists that belong to the metamorphic range north of the Yellowstone River. This is at an elevation of 6,000 feet.

On the south side of the third cañon, opposite the mouth of Hell Roaring Creek, is a massive promontory composed of conglomerates, in which are very numerous intercalated beds of sandstones and shales. In the steeper faces of this promontory, many fine trunks are exposed. In 1872, Dr. Peale obtained some very perfect specimens of fossil leaves from these beds, on the Elk Creek side, which were determined by Professor Lesquereux to be of Eocene types. The walls of the cañon in the vicinity of Hell Roaring Creek are formed of the same series of rocks, which occur also at a number of points on the river between Elk Creek and the lower falls.

In the valley of the East Fork, the sedimentary formations of the Volcanic Tertiary reach their maximum developement. Here they rest upon the unevenly eroded surfaces of the palæozoic and granite rocks, and form a great part of the mountain ranges that enclose the valley. They are horizontal and apparently conformable throughout the entire thickness of 5,500 feet. The greater part of this immense group of strata is filled with the silicified remains of a multitude of forests.

The section given in the accompanying plate occurs in the north face of Amethyst Mountain, opposite the valley of Soda Butte Creek, and includes upwards of 2,000 feet of strata. The bed of the river is at an elevation of 6,700 feet above the sea, and the summit of Amethyst Mountain, 9,400. On the north side of the valley, near the mouth of Soda Butte Creek, there are between 300 and 400 feet of Carboniferous strata exposed along the base of the mountain slope. On the south side, occasional ledges of limestone appear above the detrital deposits. Thin sheets of basalt cover the flat part of the valley, which is here less than a mile in width.

The north face of Amethyst Mountain does not present as abrupt a profile as that given in the section, the middle part only being so precipitous. At the base and top there are comparatively gentle slopes; nevertheless, the actual stratigraphical conditions are truthfully represented.

As we ride up the trail that meanders the smooth river-bottom, we have but to turn our attention to the cliffs on the right hand to discover a multitude of the bleached trunks of the ancient forests. In the steeper middle portion of the mountain face, rows of upright trunks stand out on the ledges like the columns of a ruined temple. On the more gentle slopes farther down, but where it is still too steep to support vegetation, save a few pines, the petrified trunks fairly cover the surface, and were at first supposed by us to be the shattered remains of a recent forest.

In ascending one of the steep spurs that project from the main wall, the strata were found to consist, toward the base, of shales and fine-

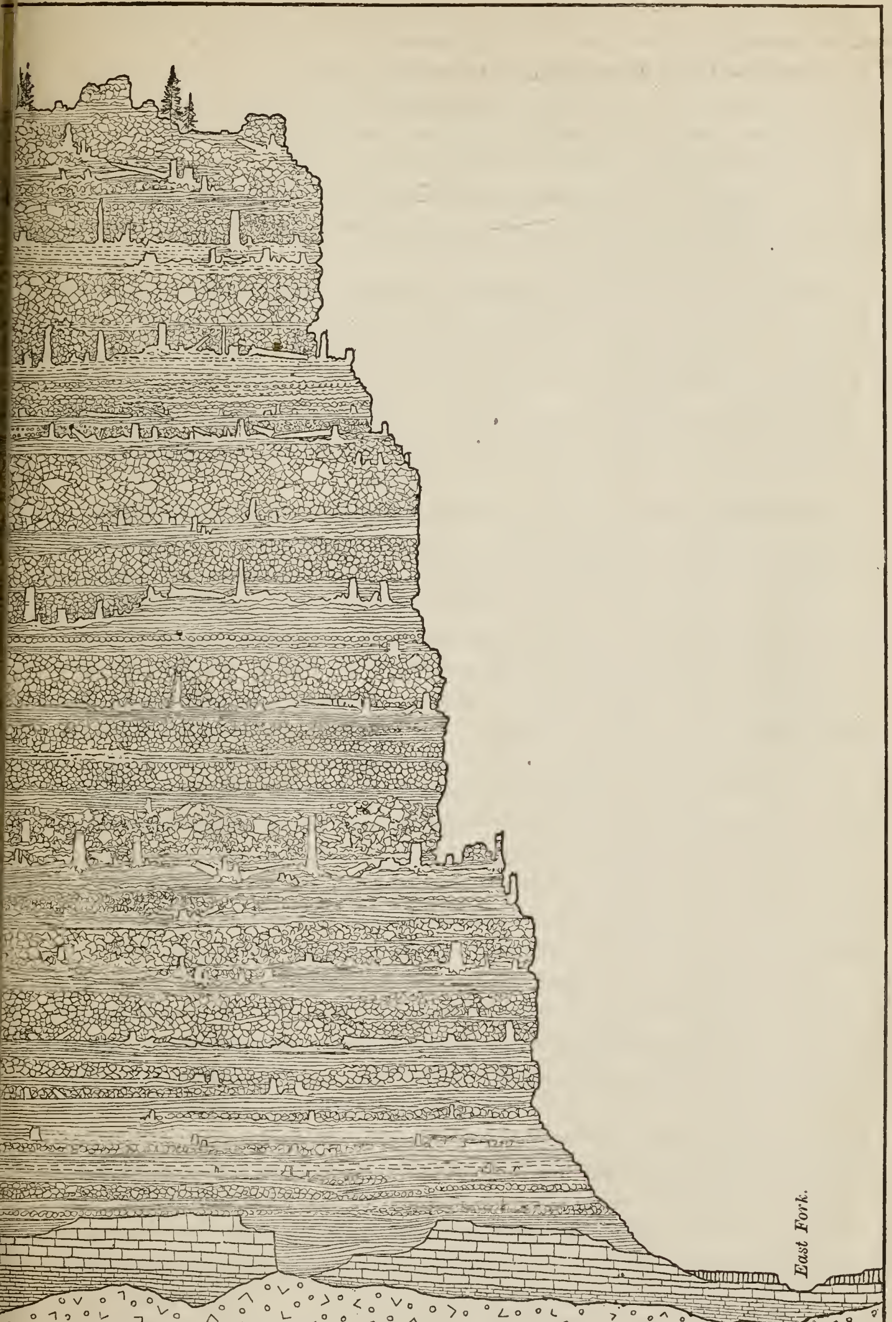


FIG. 1.—Section in the north face of Amethyst Mountain.

grained sandstones. Higher up conglomerates occur, and still higher coarse conglomerates and breccias prevail. Interbedded with the massive, irregular beds of the latter rocks are always thin layers of sandstones and shales. The sandstones are fine-grained, thinly bedded, and contain more or less tufaceous material. Their prevailing color is greenish and greenish-gray. They are apparently composed chiefly of materials derived directly or indirectly from volcanic sources. In no case are pebbles of quartz or other granitic constituents found in either the sandstones or conglomerates.

The exposures of strata in the first three or four hundred feet at the base are not good, and but few of the silicified trunks appear above the covering of vegetation. At the height of 500 feet, the occurrences become very numerous, and the great size and fine state of preservation of many of the trunks was a matter of much surprise. Prostrate trunks, 50 and 60 feet in length, are of frequent occurrence, and not a few of these are as much as 5 or 6 feet in diameter.

The standing trunks are generally rather short, the degradation of the compact enclosing strata being so slow that the brittle trunks break down almost as fast as they are exposed. In many cases the roots are exposed, and may be seen penetrating the now solid rock with all the original ramifications One upright trunk, of gigantic proportions, rises from the enclosing strata to the height of twelve feet. By careful measurement it was found to be ten feet in diameter, and as there is nothing to indicate to what part of the tree the exposed section belongs, the roots may be far below the surface, and we are free to imagine that there is buried here a worthy predecessor of the giant *Sequoias* of California. Although the trunk is hollow, and partly broken down on one side, the woody structure is perfectly preserved, the grain is straight, and the circles of growth distinctly marked. The bark, which still remains on the firmer parts, is four inches thick, and retains perfectly the original deeply lined outer surface. Specimens of the wood and bark were collected, but no microscopic examinations have been made. It is clear, however, that the tree was not a conifer. The strata which enclose this trunk are chiefly fine-grained greenish sandstones, indurated clays, and moderately coarse conglomerates. They have been built around it as it stood in comparatively shallow, but doubtless quiet waters. As would naturally be expected, these strata contain many vegetable remains: branches, rootlets, fruits, and leaves are extensively enclosed. One stratum of sandstone that occupies a horizon nearly on a level with the present top of the giant tree contains a great variety of the most perfectly preserved leaves. Such specimens as we were able to bring away with us have been submitted to Professor Leo Lesquereux for identification. They are found by him to belong to the Lower Pliocene or Upper Miocene, and correspond in a number of their species with the Chalk Bluffs specimens of Professor Whitney. They include—

Aralia Whitneyi,
Magnolia lanceolata,

Laurus canariensis,
Tilia (new sp.),
Fraxinus (new sp.),
Diospyros (new sp.),
Cornus (new sp.),
Pteris (new sp.),
Alnus (new sp.), and a
Fern (new sp.).

It will be observed that most of these species are new, which was also the case with the collection of Professor Whitney. It is also worthy of remark that none of the genera are identical with those of the Elk Creek locality previously mentioned. The stratigraphical relations of the two localities cannot easily be made out, as they are separated by fifteen miles of broken country in which the strata are obscured by igneous flows and Quaternary drift. The Elk Creek strata are lower by fully one thousand feet.

As far above the leaf-bearing horizon as I was able to ascend, the silicified trunks were very numerous and well preserved, and, by the aid of a field-glass, others could be detected in all parts of the cliff to the highest stratum.

At another point, nearly a mile farther east, I climbed the rugged walls of the mountain for the purpose of examining a number of large trees that were visible from below. Trunks and fragments of trunks were found in great numbers and in all conceivable positions. In most cases the woody structure is well preserved, the trunks have a tendency to break in sections, and on the exposed ends the lines of growth, from center to circumference, can be counted with ease. In many cases the wood is quite completely opalized or agatized, and such cavities as existed in the decayed trunks are filled with beautiful crystals of quartz and calcite. Our party was so fortunate as to procure some very handsome specimens of amethyst and ferruginous quartz. It is a matter worthy of observation that nearly all of the beautiful crystals that occur so plentifully in this region have been formed in the hollows of silicified trees. The same fact has been noticed in regard to similar crystals in many parts of the West, and notably in the case of the smoky quartz of the Pike's Peak region in Colorado.

The silicifying agents have been so unusually active in the strata of the Volcanic Tertiary that not only are all organic remains thoroughly silicified, but all cavities in the loosely bedded rocks and all fracture-lines in the strata are filled with chalcedony or other forms of quartz.

On reaching the heavily bedded conglomerates of the upper third of the cliff, I found the trees still more perfectly preserved. Many of the trunks are twenty and thirty feet in height. Their roots are in most cases imbedded in the layers of finer-grained materials, in which they grew, while the battered and branchless trunks are encased in the coarse conglomerates and breccias. These latter rocks are composed chiefly of basaltic fragments, many of which are of great size; there is, however, always enough tufaceous and other fine-grained material to fill in the interstices and act as a cement. These beds are massive and irregular, and seem to have accumulated too fast to be thoroughly redistributed by the waters. Only the stronger trees of the forest seem to have withstood the fierce storms of rocks that must have prevailed at the period of their entombment, as the smaller trunks and branches are prostrate or totally destroyed. In most cases where upright trunks penetrate the entire thickness of an enclosing bed, the tops may be seen to terminate with the upper surface of that bed, as if causes had acted at the beginning of the deposition of the succeeding stratum to plane down the irregularities of the old surface. In due course of time, this succeeding stratum produced its growth of forest, which followed its many predecessors into the subterranean depths, and in its turn was buried by the rapidly accumulating conglomerates. This remarkable alternation of events seems, in a general way, to have been kept up from the beginning to the end of the period.

The very precipitous character of the cliffs prevented me from reaching the upper part of the wall at this point, but I succeeded in making my way to the summit of the mountain at two other points, and found that everywhere the section was practically the same.

On the opposite side of the valley the same conditions were observed: the fossil trees occur at the highest point reached, 3,000 feet above the river. The ranges that form the rim of this valley on the north and east reach an elevation of 11,500 feet, and as the conglomerates may be seen reaching and forming the loftiest summits without perceptible break or change of character, it is probable that they will be found to enclose the remains of forests throughout.

On some of the higher summits to the east of Yellowstone Lake, similar stratified conglomerates contain silicified wood in a very fragmentary state. These conglomerates are composed mainly of basaltic and trachytic materials, but contain large quantities of fragments of sandstones and quartzites, which leads to the conclusion that portions of the earlier Tertiary strata have been broken up and ejected with the igneous products. It is quite probable that these strata were among the later products of the Volcanic Tertiary age proper. They are generally found abutting against masses of unstratified igneous materials that probably mark the sites of islands which were doubtless volcanic centers. I find that as we recede from these centers of eruption the strata diminish very perceptibly in thickness and coarseness of materials, and have at the same time a very perceptible dip toward the surrounding valleys. One is at times led to suspect that portions, at least, of these beds are of subaërial formation, as is the case with extensive strata about the cones of modern volcanoes, but there are a multitude of facts that go to prove that the greater part of the formations of this age were rearranged or sedimented in water.

As to the character of the seas or lakes in which the Volcanic Tertiary beds were laid down, it is clear that their waters were fresh, but as to their extent or distribution little is known. The formations cover or have covered an area of not less than 10,000 square miles, but they lie at a much greater elevation above the sea than the formations of synchronous lakes of neighboring provinces, and, so far as is known, have no actual connection with them.

It has been suggested by some one that these coarse volcanic strata may have been formed in very restricted bodies of water held high amongst the mountain ranges; but lakes cannot exist without barriers, and as has already been shown, the conglomerates, although naturally disintegrating more rapidly than any of the older rocks, now form the summits of many of the highest peaks that face the eastern plains, and the basins in which they were formed must have had free communication with the lowlands to the west, from the beginning to the end of the period.

For my present purpose it is sufficient to know that the bodies of water of this period were of sufficient extent not to be greatly affected in level by the filling-in of volcanic products or by the oscillations of the district under discussion, since we can have no correct measure of those oscillations of the surface which define the thickness and decide the character of strata without the barometer-like records of a sea-level.

The change of level produced by the great oscillation that preceded the Volcanic Tertiary period, and brought the lofty ranges of this region into existence, cannot fall far short of 20,000 feet. In order to reach these figures, we have but to add to the full thickness of the palæozoic and mesozoic strata the present elevation of the granitic ranges above the lowest observed stratum of the Tertiary rocks. At the beginning of the deposition of the Volcanic Tertiary rocks, however, the upward movement had ceased. The land had undergone enormous erosion, and subsidence had commenced. The great ranges that had lifted their crests to such lofty heights were again sinking beneath the sea. This subsidence did not cease until all, or nearly all, of the mountain peaks were submerged. It is in the strata deposited during this great subsidence that we must look for evidences of conditions and events that made the entombment and preservation of a vertical mile of forests possible.

The Yellowstone Valley, from the head of East Fork to the Lower Cañon, is carved out of strata which were formed along the west and south bases of the main eastern range of mountains. In many places the river has penetrated the full thickness of Tertiary strata, and has cut down into bodies of metamorphic rocks that at the beginning of the age were promontories or islands. It is plain, therefore, that those parts of the tree-bearing strata examined, were deposited along a shore-line, or, at least, near the borders of the Tertiary lake. Over large districts there must have been, during the period of general subsidence, a frequent alternation of land and sea. Land would have to exist while the forests grew and matured; water would have to cover the same area to deposit the succeeding stratum; and again this stratum would have to rise above the water before a second forest could grow. There are two ways in which this result could be brought about. In a district subject to such intense volcanic action as this must have been, a succession of minor oscillations might have been associated with the general subsidence, so that large areas of the lake border districts would be alternately above and beneath the sea, or, as was doubtless often the case, the shallow portions of the sea became filled up with the rapidly accumulating ejecta, and sub-aërial deposits of sufficient depth were laid down to allow the growth of forests, which, in time, were depressed by the general subsidence, to be buried by a succeeding stratum of the volcanic débris. But this latter method was not the ordinary one, as is attested by the fact that many of the forests have grown in beds of fine-grained material that must have been formed beneath the surface of the water.

I shall, however, not attempt to pursue this matter farther until all the data and materials collected have been examined. A thorough study of the various volcanic rocks will probably throw much light upon this very interesting group of strata.

VIII.
Fqk.U.S.

DEPARTMENT OF THE INTERIOR.
UNITED STATES GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES.
F. V. HAYDEN, U. S. Geologist-in-Charge.

FOSSIL ORTHOPTERA

FROM

THE ROCKY MOUNTAIN TERTIARIES.

BY

SAMUEL H. SCUDDER.

[EXTRACTED FROM BULLETIN OF THE GEOLOGICAL AND GEOGRAPHICAL SURVEY OF THE TERRITORIES, No. 6, SECOND SERIES.]

WASHINGTON, February 8, 1876.

FOSSIL ORTHOPTERA FROM THE ROCKY MOUNTAIN TERTIARIES.

By Samuel H. Scudder.

Homœogamia ventriosus.—The remains upon which this species is based consist of the apical portion of the ventral surface of a cockroach's abdomen found by Mr. T. L. Mead at Castello's ranch, South Park, Colorado. Five segments are seen in natural juxtaposition, showing that the apical portion of the abdomen was very regularly rounded, almost exactly semicircular; the terminal segment presenting no break in the regular continuity of the curve. This segment was ample, broader than long, and probably neither very tumid nor greatly keeled; for in the present perfectly flattened condition of the fossil there is neither break nor folding of the integument; the two segments following this are very strongly arched (the penultimate being semicircular) and greatly contracted at the middle, so that this portion is not less than half as long as the lateral parts; the anterior border of the antepenultimate segment is straight along the middle; the segment anterior to this is also arched, though not strongly, is oppositely sinuate (as are, to a less extent, the segments posterior to it), and also much contracted in the middle, so as to be less than half as long as at the sides; while its predecessor is slightly arcuate in the opposite direction (probably exactly transverse in life), and equal or subequal throughout. All the segments are uniformly, rather abundantly, and very delicately granulate throughout. There is no trace of cerci, but the place where they should occur is too broken to assert that they did not exist externally; still the conformation of this region would lead one to suppose that they must have been excessively minute, and perhaps altogether concealed within the segments, as in *Cryptocercus* Scudd.

Length of fragment, 8^{mm}; width of same, 12.25^{mm}; length of terminal segment, 3.6^{mm}; width of same, 6.3^{mm}; length of antepenultimate segment in the middle, 0.6^{mm}; at the sides, 1.85^{mm}.

I have referred this species to *Homœogamia* with some doubt; on some accounts, it would seem to be more nearly allied to *Polyphaga*, but, as the specimen is too fragmentary to allow of more exact determination, I have preferred to place it in the New World genus, rather than in its close ally, which is restricted to the Old World; possibly it should be referred to neither, but to a new group.

A great many fossil cockroaches have been found, mostly in the Carboniferous formation. Nearly all are described from tegmina. Only a few species have been discovered in the Tertiaries; and one of these, found in Parschlug in Steiermark, has been referred by Heer* to *Heterogamia*, a name used to include both *Polyphaga* and *Homœogamia*.

Labidura tertiaria.—A single fairly-preserved specimen (No. 1725) was found near Castello's ranch, South Park, Colorado, by Mr. Jesse Randall, and brought home by the United States Geological Survey of the Territories. The specimen is a female, as shown by the number of the abdominal segments. The head, which is badly preserved, is of about equal length and breadth behind the labrum, so that as a whole it is

---

*Heer, Insekt.Fauna Oening. ii, 1, pl. 1, fig. 1.

longer than broad, but it is slightly narrower than the pronotum, and has large eyes, reaching back nearly to the hind border—characters which are scarcely in keeping with the reference of the insect to *Labidura;* with no other genus, however, does it accord so well. The antennæ are too fragmentary to furnish us any clew to their structure, and of the mouth-parts nothing can be determined. The pronotum is of about equal length and breadth, quadrate, the anterior angles bluntly rounded, the posterior border very broadly convex, the margin nowhere elevated; there is a slight but distinct median sulcation, fading posteriorly. The rest of the thorax is of the same width as the pronotum; the tegmina are twice as long as the pronotum, squarely docked at the tip; the folded wings reach more than half as far again beyond the tip of the tegmina, and, in the specimen examined, are partially opened on the right side, so as to show incompletely the peculiar rayed arrangement of the nervules. The legs are short, the femora broadest in the middle, the tibiæ moderately slender and slightly bowed; but the tarsal joints are too obscure to determine their structure; the faintness of the legs probably shows that they were paler than the body, which is of a griseous brown. The joint of the abdomen can readily be distinguished, although a portion of some of them are injured, and especially of the third segment; this renders it impossible to decide certainly whether plications were present on this segment; but there are no signs of any, either on this or on the better-preserved second segment; it would seem as if such plications should be seen, if present, at least on the second segment; for the abdomen is preserved on a partial side-view, and the portion of the second segment where plications are to be looked for is perfectly preserved. The abdomen appears to have been equal as viewed from above, although the greater fullness in depth of the middle joints gives the specimen preserved on a partial side-view a great height in the middle; the last segment is large, scarcely narrowing, and furnished with a pair of stout, straight, tapering, bluntly-pointed forceps as viewed from the side, not so long as the tegmina, and apparently curved inward at the tip. The insect is slightly smaller than the common *L. riparia* (Pall.) Dohrn.

Entire length of specimen, 19.5^{mm}; length of head, 2.2^{mm}; breadth of same, 1.75^{mm}; length of pronotum, 1.9^{mm}; breadth of same, 2^{mm}; length of tegmina, 3.6^{mm}; extent of folded wings beyond tegmina, 2.5^{mm}; length of hind femora, 2.75^{mm}; of hind tibiæ, 1.75^{mm}; of forceps, 2.5^{mm}.

Fossil earwigs are not unknown, but have been imperfectly studied. Heer gives woodcuts of two, *Forficula recta*, which he compares with *Forcinella annulipes* (Luc.) Dohrn, and *F. primigenia*, compared with the common earwig, *i. e.*, *Forf. auricularia* Linn.; he also mentions a third, *F. minuta*, compared with *Labia minor* (Linn.) Leach. These all come from the Miocene of Oeningen.* Long ago, Serres spoke of a species allied to *Forficula parallela* Fabr. and *F. auricularia* Linn. (both the same species), of which many specimens had been found at Aix in Provence.† Perhaps Mr. Oustalet, in his forthcoming memoirs on the fossil insects of Southern France, will acquaint us more perfectly with this insect; but I saw no specimens of *Forficulariæ* in his hands in 1873. One or two species are also reported from Prussian amber. Burmeister says that the Berlin Museum possesses a specimen "having short filiform antennæ, composed at most of sixteen joints, gradually increasing in size, and a short, straight ovipositor [forceps]. It is of the size of *Forficula minor*, but is still a larva."* And Germar writes that, up to 1856, but a single specimen of an earwig had been found in amber, a larva, agreeing so completely with the full-grown larva of *Forf. auricularia* that description and illustration are superfluous.† The full-grown larva of *F. auricularia*, however, has but fourteen, and even the perfect insect but fourteen or fifteen, joints in its antennæ; and the forceps are neither short nor straight, but nearly as long as the abdomen, and incurved at the tip. It would seem probable, therefore, that these authors were writing of different insects, and that Germar overlooked Burmeister's statement. Gravenhorst, also, is said to refer to a German species from amber; but I have not yet been able to examine the reference to it. Finally, Massalongo describes and figures‡ a species from the Tertiaries of Monte Bolca, which he calls *Forficula bolcansis*, and which again he compares to *F. auricularia* Linn. This species, which in point of fact is much nearer *F. albipennis* Muehlf. than *F. auricularia*, is even more perfect than ours, and seems to be a true *Forficula*. The same may probably be said of Heer's species, or at least of the two which are figured (none are described); but in these cases we have only a few abdominal joints and the forceps from which to draw any conclusion. It is by no means improbable that the two insects figured by Heer are different sexes of the same species.

---

* Heer, Urwelt der Schweiz, 367, figs. 226–227.

† Serres, Géognosie des terrains tertiaires, 225.

---

[*] Burmeister, Handb. of Entom., Engl. trans., 579.
[†] Berendt, Org. Reste in Bernstein, ii, i, 33.
[‡] Massalongo, Strid. Pal., 15-16, pl. 1, figs. 5-7.

IX J.k.165

ON THE SUPPOSED ANCIENT OUTLET OF GREAT SALT LAKE.

By A. S. Packard, Jr.

While attached for a few weeks this summer to Hayden's United States Geological and Geographical Survey of the Territories, I learned from conversations with General P. E. Connor, late of the United States Army, and others, of the supposed existence of an old river-bed, which probably drained, in part at least, the lake which in Quaternary times formerly filled the Salt Lake Valley. I have been unable to find any reference to such an outlet in the report of Frémont, Stansbury, or Hayden. The following quotation, extracted by Professor Hayden from the second volume of the Pacific Railroad Reports, page 97, shows, on the contrary, that no outlet has been supposed to exist:—

"These banks are not peculiar to the vicinity of this lake of the basin, but were observed near the lakes in Franklin Valley, and will probably be found near other lakes, and in the numerous small basins which united form the Great Basin. They clearly seem to have been formed and left dry within a period so recent that it would seem impossible for the waters which formed them to have escaped into the sea, either by great convulsions opening passages for them, or by the gradual breaking-up of the distant shore (rim of the basin), thus draining them off without leaving abundant records of the escaping waters, as legible at least as the old shores they formed."

My object at the present moment is simply to call the attention of geologists and geographers to the facts stated by General Connor, suggested by railroad-surveys made in Southern Utah. An intelligent man who has lived for seven years on the shores of Salt Lake, and also Mr. J. E. Clayton, mining-engineer, of Salt Lake City, who has traveled much in Southern and Central Utah, have kindly given me confirmatory information regarding this ancient river-bed.

It appears also that there is a very general impression that such an outlet formerly existed and drained the waters of the lake into the Gulf of California or possibly into the Pacific Ocean emptying near San Diego.

General Connor, my original informant, has kindly indicated, on a map of Utah and adjoining regions lying southward, the course of this supposed river-bed. The rim of the present Salt Lake is lowest at Skull Valley, which opens into the lake at a point on the western side of the lake due west of the northern extremity of Antelope Island. The outlet is said to be somewhat over one hundred feet above the present level of the lake. The river-bed has been traced by railroad-surveyors for a distance of over one hundred miles, in a southerly direction, to the Sevier Lake Valley, passing west of Sevier Lake.

Beyond this, the course of the river-basin is purely conjectural; but the indications are that the river poured into the Colorado River near the confluence of the Muddy River and Rio Virgen. It is possible that it may have had an independent outlet into the Dry Lake Basin, the valley of which is seventy feet below the present ocean-level, and situated north of east of San Diego. From here it may have emptied into the head of the Gulf of California, or turned westward and sought the Pacific Ocean at or somewhere near the bay of San Diego.

These suggestions made by practical railroad-engineers are offered for the consideration of geologists. The writer has not observed personally any facts bearing on the subject. Granting, however, that the lake was thus drained, and in view of the fact that it is one of the few lakes in the West that has at present no outlet, it seems reasonable to suppose that the lake was a fresh-water inland sea while above this level, and that after it ceased to have an outlet the waters decreased and became salt partly through the agency of evaporation and the probable supply of saline matter from salt-springs around the border of the lake, and possibly from salt-deposits in the surrounding rocks and soil.

From these facts, it is not difficult to understand why the Great Salt Lake became a dead sea, or gigantic brine-pool, while Utah Lake, with an outlet, the Jordan River, remains a fresh-water lake. I was unable to ascertain the exact height above the present level of the lake of this ancient river-bed, but was told it was one hundred feet or over.

Morrill - Feb 1966. Pumpelly Collect

MDF